DEPARTMENT OF COMMERCE WEATHER PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the federal government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National Ocean Service (NOS); and the Office of NOAA Corps Operations (NC).

NATIONAL WEATHER SERVICE

The National Weather Service (NWS) has the principal responsibility for the plans and operations of the basic weather, hydrologic and climate services and certain specific applied services. The NWS mission is to provide weather, water and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas to help protect life and property and enhance the national economy. NWS data and products form a national information data base and infrastructure which can be used by other governmental agencies, the private sector, the public and the global community. In support of this mission, NWS:

- Issues warnings and forecasts of weather, flood, and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the United States and its possessions.
- Develops and operates national meteorological, hydrological, climate, and oceanic service systems.
- Performs applied meteorological, hydrological, and climate research.
- Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.
- Participates in international hydrometeorological activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

The basic enabling legislation and authority for weather services are summarized as follows:

- Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the United States Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for provision of weather observations and services to aviation.
- Reorganization Plan 2 of 1965 placed the "National Weather Service" in the newly created Environmental Science Services Administration (ESSA).
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).

SERVICES

NWS provides around-the-clock weather and flood warning and forecast services. The NWS provides services through a national network of 121 Weather Forecast Offices (WFOs) and 13 River Forecast Centers (RFCs) (Figure 3-DOC-1) that collect data, prepare state and local warnings and forecasts, and disseminate information to the population both directly and indirectly through the mass media. In preparing local warnings and forecasts, WFOs use value-added forecast guidance prepared by the nine National Centers for Environmental Prediction (NCEP) (Figure 3-DOC-2). The core mission of the NWS also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

Weather Warnings and Forecasts. NWS forecasters at WFOs issue local warnings for severe weather such as tornadoes, severe thunderstorms, floods, and extreme winter weather. WFOs prepare forecasts for zones which are comprised of several counties that experience similar weather. Each WFO has forecast responsibility for several zones. WFOs also provide the main field forecast support for the marine and aviation programs as well as guidance for the fire weather program supporting federal lands management and wildfire control.

Figure 3-DOC-1. Locations of NWS Weather Forecast Office

Aviation Weather Services. The NWS provides a broad range of services in support of the aviation community. The WFOs prepare terminal airport forecasts four times a day with amendments as needed for over 500 public-use airports in the United States and in the Caribbean. These offices also produce about 300 individual route-oriented forecasts three times a day for the 48 contiguous states.

NCEP's Aviation Weather Center (AWC) and the Alaska Region's Aviation Weather Unit prepare area forecasts three times daily describing general aviation weather conditions over the lower 48 states and Alaska, respectively. These two specialized aviation weather centers, along with WFOs in Hawaii and Guam, issue in-flight advisories of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low-level winds.

NWS Center Weather Service Units located in each of the 21 Federal Aviation Administration Air Route Traffic Control Centers provide direct meteorological support to en route centers, Terminal Radar Approach Controls, and airport towers.

The NWS provides a service to international aviation as one of the International Civil Aviation Organization's two World Area Forecast Centers. NCEP's Environmental Modeling Center supplies global gridded model data of temperature, winds, and humidity twice a day for flight levels from 5,000 feet to 45,000 feet. The AWC prepares forecasts of significant weather for approximately two-thirds of the globe four times a day for thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence, moderate or severe icing, and cumulonimbus cloud associated with the above, from 25,000 to 63,000 feet. The forecast charts also include information on jet streams and tropopause heights. This information is transmitted over the International Satellite Communications System with coverage in the Americas, Caribbean, western portions of Europe, the Pacific, and eastern Asia.

Within the framework of the international airways volcano watch, the NWS, through NCEP, shares management responsibility with NOAA's National Environmental Satellite, Data and Information Service (NESDIS) for Volcanic Ash Advisory Centers in Alaska and Washington.

Marine Weather Services. Using NCEP weather analysis and forecast guidance, marine weather forecasters at coastal and Great Lakes WFOs issue wind, wave, weather, and ice warnings, forecasts, and other information for populations living along the coastal waters and the Great Lakes. Principal products include small craft and heavy surf advisories, coastal flood warnings, coastal waters forecasts, sea and swell forecasts, and special weather forecasts to aid in the containment and clean up of oil spills and other hazardous substances in the marine environment.

Fire Weather Services. NWS offices provide routine pre-suppression and wildfire weather support to federal and state land management agencies. Upon request, NWS provides site-specific forecasts for prescribed burns on federal lands. The NWS deploys a national cadre of specially-trained Incident Meteorologists (IMETs) to large wildfires and coordination centers for on-site weather support. IMETs use weather instrumentation, telecommunications, and display equipment to aid in on-site forecast preparation and briefings. NCEP's Storm Prediction Center provides daily fire weather guidance that highlights areas with high fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters such as low relative humidity, strong winds, and dry lightning activity.

Tsunami Warnings. Tsunami watches and warnings for Pacific Ocean areas and Alaska are prepared and issued by the Tsunami Warning Center at Ewa Beach, Hawaii, and the regional center at Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories and sea-level observing stations which operate on a cooperative basis. The centers use the data to prepare watches and warnings covering all United States territories and states bordering on the Pacific Ocean and disseminate this information to WFOs, federal and state disaster agencies, military organizations, private broadcast media, and other facilities that warn the public.

National Centers for Environmental Prediction.

Over the last several decades, NWS has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. Further improvements will be realized in the severe weather and flood warnings program as a result of improvements in higher resolution, centrally prepared weather guidance products out to Day 5, implementation of NWS systems upgrades, advanced observations from the planned geostationary and polar-orbiting satellites, and the development of mesoscale predictive techniques for NWS field operations. While the NWS field structure focuses more on warnings and short-range forecasts, NCEP serves a broader, national mission where national centers provide products based on output from numerical models, statistical adjustments to model fields, and value-added products prepared by national center forecasters. This NCEP product suite is transmitted to the WFOs in digital form, where forecasters use the products to prepare local forecasts.

NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models -- the basis for NWS predictions. NCEP provides an integrated suite of forecast guidance and specific forecast products from the short-term through seasonal and interannual time frames. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value-added forecast guidance products for NWS field offices and other users.

Storm Prediction Center. The Storm Prediction Center (SPC) focuses on hazardous weather events such as severe thunderstorms, tornadoes, extreme winter weather, and fire weather with emphasis on the first few hours of the forecast period. Other products issued from the SPC give the WFOs specific guidance on the probability and intensity of severe weather occurrences for regional and local geographic scales. The SPC also issues national outlooks for severe weather out to two days.

Hydrometeorological Prediction Center. The Hydrometeorological Prediction Center (HPC) prepares quantitative precipitation forecasts (QPF) used by WFOs to develop local rainfall, snow, and ice forecasts and by the RFCs to develop local river and flood forecasts. The HPC provides special QPFs and coordinates with other federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analyses and forecasts out to seven days of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community.

Marine Prediction Center. The Marine Prediction Center (MPC) handles United States international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). This center provides one-stop-shopping for marine interests operating outside the domain of coastal WFOs. The MPC provides weather and sea state warnings and forecasts for the high seas of the Northern Hemisphere north of 30 degrees for planning and operational purposes. MPC warnings and products go directly to ships and are vital for the protection of life and property at sea.

The MPC also coordinates forecasts with WFOs with coastal responsibilities. Coastal WFOs have responsibility for local forecasts and warnings that go out to approximately 60 nautical miles; for the high seas beyond, the MPC has responsibility.

Tropical Prediction Center/National Hurricane Center. The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). TPC/NHC services include advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific Oceans, the Caribbean Sea, and the Gulf of Mexico, including the portions of the coastline threatened by such storms.

In addition, TPC forecasters provide marine analyses and forecast products for the same areas of responsibility. The TPC/NHC provides guidance,

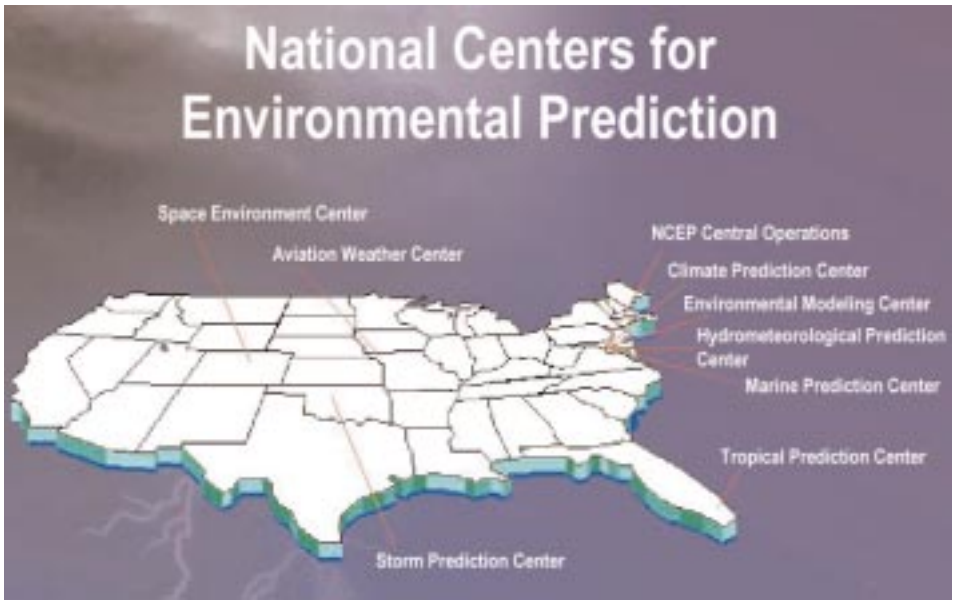


Figure 3-DOC-2. Locations of NCEP centers.

coordination, and tropical weather expertise to WFO forecasters, the media, and private industry.

Aviation Weather Center. The Aviation Weather Center (AWC) provides weather forecasts to the aviation community under an international agreement through the International Civil Aviation Organization. The AWC provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and en route aircraft operations for the United States, the Atlantic and Pacific routes in the Northern Hemisphere, and some routes in the Southern Hemisphere.

The AWC also produces guidance products used by WFOs to support airport terminal forecasts. Thus, the AWC produces large-scale, global aviation functions centrally, while the WFOs customize local aviation products based on centralized guidance provided by the AWC and local observations.

Climate Prediction Center. The Climate Prediction Center (CPC) produces services consisting of operational prediction of climate variability, monitoring of the climate system and development of data bases for determining current climate anomalies and trends, and analysis and assessment of their origins and linkages to the rest of the climate system. These services cover time scales ranging from weeks to seasons, and cover land, ocean, and atmosphere extending into the stratosphere. WFOs, as well as the public, private industry, and the international research community use CPC climate services.

Space Environment Center. The Space Environment Center (SEC) provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues specific predictions of the space weather activity level for the next three days and more general predictions up to several weeks in advance, as well as weekly summaries of observed solar-terrestrial conditions.

Environmental Modeling Center. The Environmental Modeling Center (EMC) improves NCEP's numerical weather, water, and climatic predictions through data assimilation and computer modeling. In support of the NCEP operational missions to provide ocean prediction, mesoscale prediction (thunderstorms, hurricanes, tornadoes, etc.), and global prediction, EMC develops, adapts, improves, and monitors data assimilation systems and models of the atmosphere, ocean, and atmosphere/ocean system. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. The EMC integrates research and technology through collaborative model development projects. These interactions serve as an efficient and effective interface between NCEP and the scientific community that develops ideas, models, and techniques to improve NCEP products. The EMC also conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community.

NCEP Central Operations. The NCEP Central Operations (NCO) is responsible for all aspects of NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems, as well as the workstations used by NCEP forecasters to access model output and other data necessary for producing guidance products. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications-related services that link individual NCEP activities together. The NCO is the focal point for establishing and executing policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO houses and runs the supercomputer facility that generates all NCEP model products. The NCO provides the technical transition between the research and development of numerical weather and climate prediction models and their operational use. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS mainframe and supercomputer systems, forecaster workstations, and personal computers.

SUPPORTING RESEARCH

The NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather and flood warning and forecast services to the public.

Meteorological Research. The NWS conducts meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques for weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.

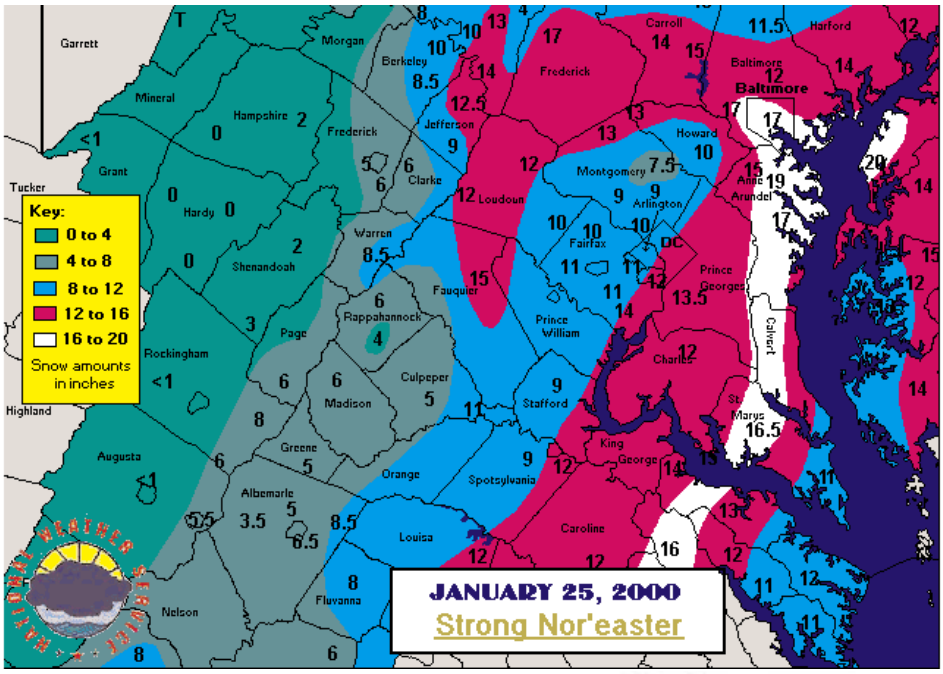


Figure 3-DOC-3. Quantitative Precipitation Forecast (above) compared with observed precipitation amounts (right).

- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.

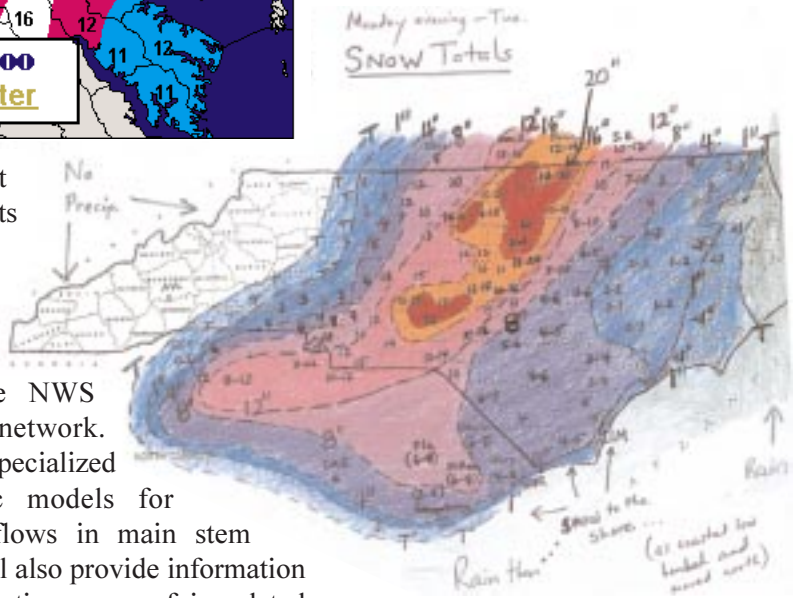
Hydrologic Research. The NWS develops, implements, and operationally supports improved hydrologic, hydraulic, and hydrometeorological models and manages hydrologic data and enhanced quality control procedures to support national flood and water resources forecasting. Research encompasses the following areas:

- Improvements to the Ensemble Streamflow Prediction (ESP) system and its complimentary models in the NWS River Forecasting System. Research, development, and implementation of improved ESP procedures are a large component of the NWS' Advanced Hydrologic Prediction Services (AHPS) initiative.
- Specialized flood and flash flood forecasting procedures using linked hydrologic, hydraulic, and meteorological models. Major research areas include developing distributed hydrologic models that use high resolution precipitation data from the NWS radar network. Highly specialized hydraulic models for routing flows in main stem rivers will also provide information for generating maps of inundated areas.
- Development of improved multi-sensor precipitation estimates for input estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge, and satellite rainfall estimates are merged to produce optimum rainfall analyses.

MODERNIZATION AND BEYOND

The NWS completed a modernization program in August 2000 that has ushered in a new era for severe weather and flood warning and forecast services. Important advances in the atmospheric sciences, coupled with major new technological capabilities for observing and analyzing the atmosphere, have provided unprecedented improvements in weather services. The NWS is operating and will continue to improve in the future, the most advanced hydrometeorological warning and forecast system in the world.

Through the WFOs, RFCs and NCEP, the NWS provides a uniform level of warning and forecast services nationwide. All of the new technologies have been deployed and are fully operational and include 314 Automated Surface Observing Systems, 123 Next Generation Weather Radars with Doppler capability, 154 Advanced Weather Interactive



Processing Systems, geostationary and polar-orbiting satellites and a new supercomputer.

Statistics verify the substantial improvements in warning and forecast accuracy and timeliness. Advance warning for tornadoes has doubled and now averages 12 minutes. Advance warning for flash floods has nearly doubled. Accuracy of severe thunderstorm warnings has increased to 84 percent. The effectiveness of NWS modernization has been demonstrated during a number of major weather events during the past decade including: the March 1993 east coast blizzard, the January 1996 winter storm in the northeast, the January 1998 ice storm in New England, flooding events in the west in 1995 and 1997, tornado

outbreaks in the southeast in 1998, El Niño-related storms, floods and tornadoes during the winter of 1997-1998, and weather support during forest fires in the West throughout the summer of 2000.

With the completion of its decade-long modernization, NWS has a unique opportunity to capitalize on the extensive investments in science and technology to continue improving its services to the Nation. Emerging scientific and technological capabilities in weather, water and climate prediction are matched by increasing national needs for improved warnings and forecasts and a more integrated NWS focus in these three scientific disciplines. The NWS is now postured to blend forecasts in these areas into a seamless suite of products and services — accurate and timely products with high resolution and in a format that will provide users the flexibility to tailor the information to their specific needs.

The characterization of a seamless suite of products and services means that by 2005 the NWS will provide weather, water, and climate forecasts for a specific geographic area from

Weather Forecast Office
Anchorage, Alaska

Weather Forecast Office
Atlanta, Georgia

Advanced Weather Interactive Processing System (AWIPS)

WSR-88D NEXRAD Weather Radar
Binghamton, New York

Figure 3-DOC-4. Modernized NWS offices and equipment.

time scales of minutes to seasons or years. Climate services will be provided months in advance to allow communities and businesses to prepare for extreme weather and water conditions. These will be further supported by forecasts that assess the threat of particular hazardous conditions (e.g., heavy precipitation or flooding) for specific areas of the country up to two weeks in advance. Finally, very precise forecasts of individual events (e.g., flash floods) will be provided hours and minutes in advance. In contrast, many of today's products and services are prepared independently of other products and services for the same geographic area. This results in potential inconsistencies and in less effective use of data and computational power. By 2005, NWS forecasts will be continuous, cumulative, consistent, relevant, and make the most effective use of data and computing power of the agency.

To achieve the above scenario of services by 2005, NWS has prepared a strategic plan for weather, water and climate services. The plan, published in August 1999, presents five goals:

- Deliver a credible, timely, and relevant suite of seamless weather, water, and climate products and services which exploit technology to the fullest to meet customer and partner needs;
- Aggressively and continually infuse science and technological advances to improve products and delivery of services that best meet and anticipate customer needs;
- Strengthen United States leadership on emerging application of weather, water, and climate information to meet environmental and economic challenges;
- Work with employees to create an organizational culture which embraces change; values service; promotes teamwork with customers, partners, and each other; and fosters innovation in mission and vision accomplishment; and
- Create a responsive support system, adaptable to changing needs and opportunities which maximize the return on investment to America.

The NWS focus through 2005 will be to harness an explosion of information technology, to strengthen linkages among the disciplines of weather, water, and climate prediction, to work more effectively with partners to improve and expand services, and to become a more responsive and efficient government agency.

The National Environmental Satellite, Data, and Information Service (NESDIS) manages United States civil operational environmental satellite systems, as well as global databases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and development and management of environmental resources (Figure 3-DOC-5).

NESDIS was established as a NOAA line office on December 1, 1982. It was formed by the merger of the former National Environmental Satellite Service (NESS) and Environmental Data and Information Service (EDIS).

NESDIS operates two primary polar-orbiting satellites in sun-synchronous orbits with equatorial crossing times in the early morning (circa 7:30 a.m. LST) and early afternoon (circa 1:40 p.m. LST). The orbits are circular, with an altitude between 830 km (morning orbit) and 870 km (afternoon orbit). These satellites orbit the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and longer-term global climate change research.

An agreement finalized with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of the polar environmental mission (circa 9:30 a.m. LST), with United States-provided payload instruments and sensors, beginning in 2003. Thus, upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission.

On October 3, 1994, NOAA, DOD, and the National Aeronautics and Space Administration (NASA) created an Integrated Program Office (IPO) to develop, manage, acquire, and operate the national polar-orbiting meteorological satellite system, subsequently designated the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The IPO is organizationally located within NOAA and is headed by a System Program Director responsible to the NPOESS Executive Committee. This committee, which includes senior representatives from the three agencies, serves as a board of directors to ensure that the overall program plans meet the needs of the three participating agencies.

The IPO concept provides each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA has overall responsibility for the converged system and is responsible to the IPO for satellite operations. NOAA is also the primary interface with the international and civil user communities. DOD is responsible to support the IPO for major systems acquisitions including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Although each agency provides certain key personnel in their lead role, each functional division is staffed by tri-agency work teams to maintain the integrated approach. The first converged satellite is expected to be available sometime toward the middle to latter half of this decade depending on when the current NOAA and DMSP programmed satellite assets are exhausted.

NPOESS will provide standard meteorological data, oceanographic, environmental, climatic, space environmental remote sensing information, as well as continuing to provide surface data collection and search and rescue capability. The IPO, in consultation with the NOAA and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services.

NESDIS is also responsible for operating two Geostationary Operational Environmental Satellites (GOES). GOES-East stationed at 75°W monitors the Atlantic Ocean, the East and Gulf Coasts, and the Midwest; GOES-West at 135°W monitors the Pacific Ocean and West Coast. Due to an impending failure of the attitude and orbit control systems on GOES-9, it was replaced by GOES-10 in July 1998. GOES-11, the next in the series of GOES, was launched on May 3, 2000. It was placed in on-orbit standby at 104°W. It will replace either GOES-8 or GOES-10, when either satellite fails.

ENVIRONMENTAL SATELLITE SERVICES

The Office of Satellite Operations (OSO) directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) and Command and Data Acquisition (CDA) stations, which command and control, track, and acquire data from these environmental satellites.

OSO took over the command, control, and communications function of the DOD's Defense Meteorological Satellite Program (DMSP) constellation in 1998. The mission of DMSP is to provide meteorological and special sensor data to users in support of world wide DOD missions. DMSP is now operated from the SOCC at Suitland, Maryland. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution.

A new ground system was developed for DMSP called Integrated Polar Acquisition and Control Subsystem.

The Office of Satellite Data Processing and Distribution (OSDPD) directs the operations of NESDIS central ground data processing facilities. It processes and distributes current weather satellite data and derived products to the NWS and other domestic and foreign users, and provides coordination and customer services for satellite direct readout and direct broadcast users. OSDPD distributes NOAA and non-NOAA environmental satellite products to the NWS National Centers and Weather Forecast Offices (WFOs), who provide further distribution to regional NWS offices and other federal, state, and private sector agencies. OSDPD is currently generating modern remapped digital data satellite products for further distribution via NOAAPORT, a satellite point-to-multi-point broadcast. NOAAPORT delivers various GOES products in virtually real-time to the Advanced Weather Interactive Processing Station (AWIPS). AWIPS, a new display and analysis workstation, enables NWS

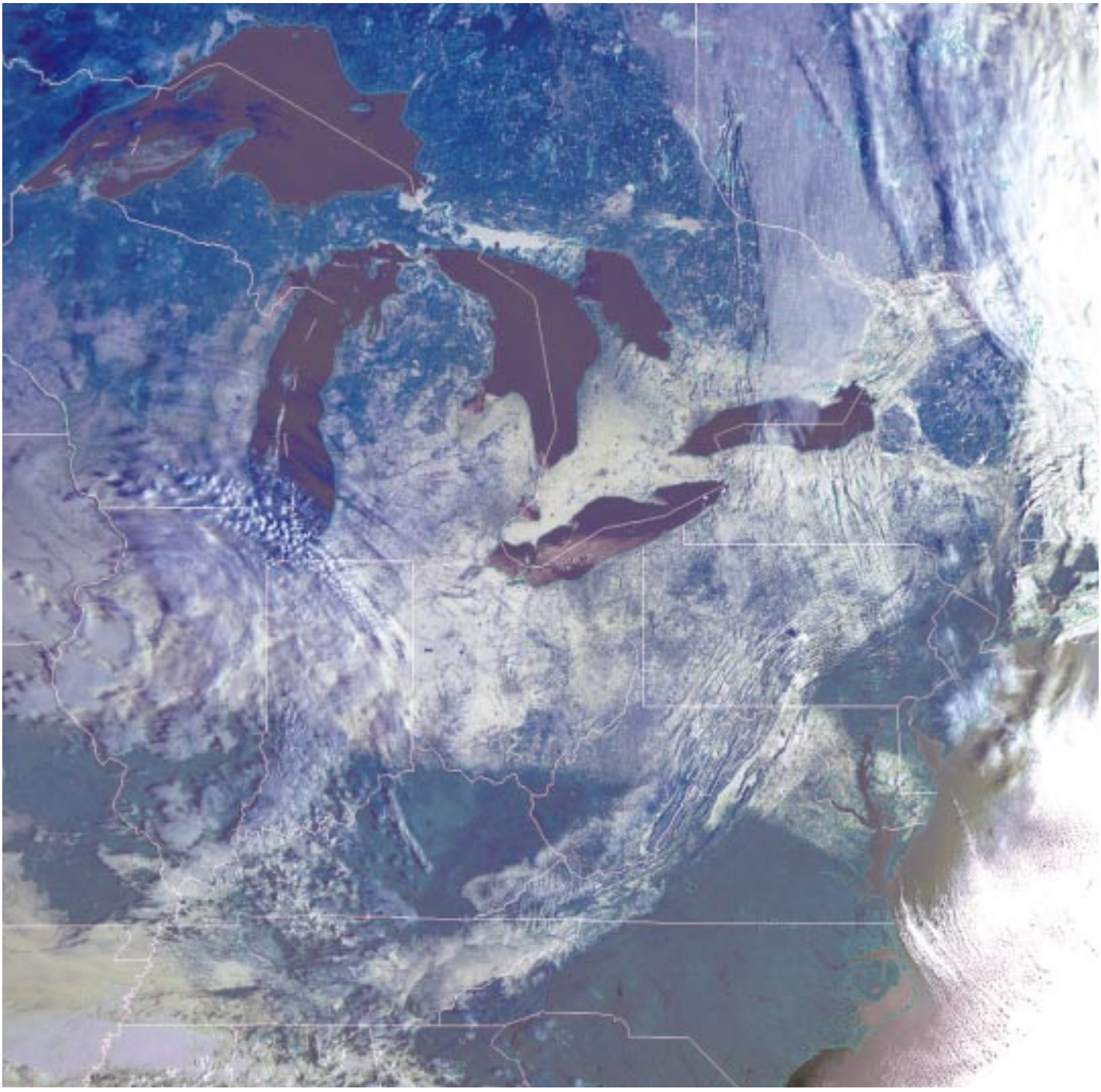


Figure 3-DOC-5. NESDIS Operational Significant Event Imagery (OSEI)--Snowstorm over Southeast United States on March 11, 1999

national centers and field sites to integrate and display satellite data for hydro-meteorological analyses. As AWIPS development and deployment proceed, NESDIS will continue to supply digital GOES images to a group of NWS sites equipped with the RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS)--a PC-based image display and analysis system. These sites acquire the images via the Internet for demonstration, evaluation, and familiarization purposes. RAMSDIS enables forecasters to perform operations such as looping, enhancement curve changes, and local image recombination.

NESDIS continued its support of the COSPAS-SARSAT Program through provision of satellites, ground stations, and alert data distribution services. Russia, the United States, France, and Canada provide the space segment and related ground systems for COSPAS-SARSAT. NESDIS operates and maintains the United States SARSAT Mission Control Center and seven ground stations. The ground stations receive Doppler signals directly from the satellites and process the information to provide the location of distress transmissions. In 1999, COSPAS-SARSAT began to incorporate Geostationary Earth Orbit Search and Rescue (GEOSAR) satellite systems as a supplement to the existing COSPAS-SARSAT polar-orbiting system. GEOSAR systems provide instantaneous alerting capability and can significantly decrease rescue times. In 1998, the COSPAS-SARSAT Council also agreed to implement new emergency beacon location protocols to provide precise location within the beacon message using the United States Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS).

National Ice Center

The United States National Ice Center (NIC), under sponsorship of the United States Navy, NOAA, and the United States Coast Guard (USCG), is tasked with providing global sea ice and Great Lakes ice information in support of shipping, cryospheric research, and other maritime activities. NIC ice guidance products are produced in a digital workstation environment using data from polar orbiting satellites, ship/shore station reports, drifting buoys, meteorological guidance products, ice model predictions, and government partners including foreign ice services. The primary remotely sensed data sources used for global and regional-scale ice mapping are visible and infrared imagery from the TIROS-N Advanced Very High Resolution Radiometer (1.1km spatial resolution) and the DMSP Operational Linescan System (0.55km spatial resolution). In areas of extensive cloud cover, the NIC utilizes Special Sensor Microwave Imager (SSM/I) sensor data (19 and 37 GHz channels) processed using the CAL/VAL and NASA Team ice concentration algorithms (Figure 3-DOC-6). These algorithms produce 25km gridded mosaic ice maps that are instrumental in the production of NIC weekly composite Arctic/Antarctic ice maps. Higher resolution ice analysis products, used to ensure the safety of navigation and protect life and property at sea, are dependent upon the availability and use of Synthetic Aperture Radar (SAR) data from the Canadian RADARSAT. Of greatest utility to NIC is RADARSAT's ScanSAR Wide mode with a 500km wide swath and 100m spatial resolution. Images are processed at four Arctic ground stations and transferred to the NIC via dedicated communication lines or via the Internet within six hours of acquisition. The NIC Science team, which assists in the transition of pertinent scientific research to operations, is presently evaluating ARKTOS, an automated expert system that uses

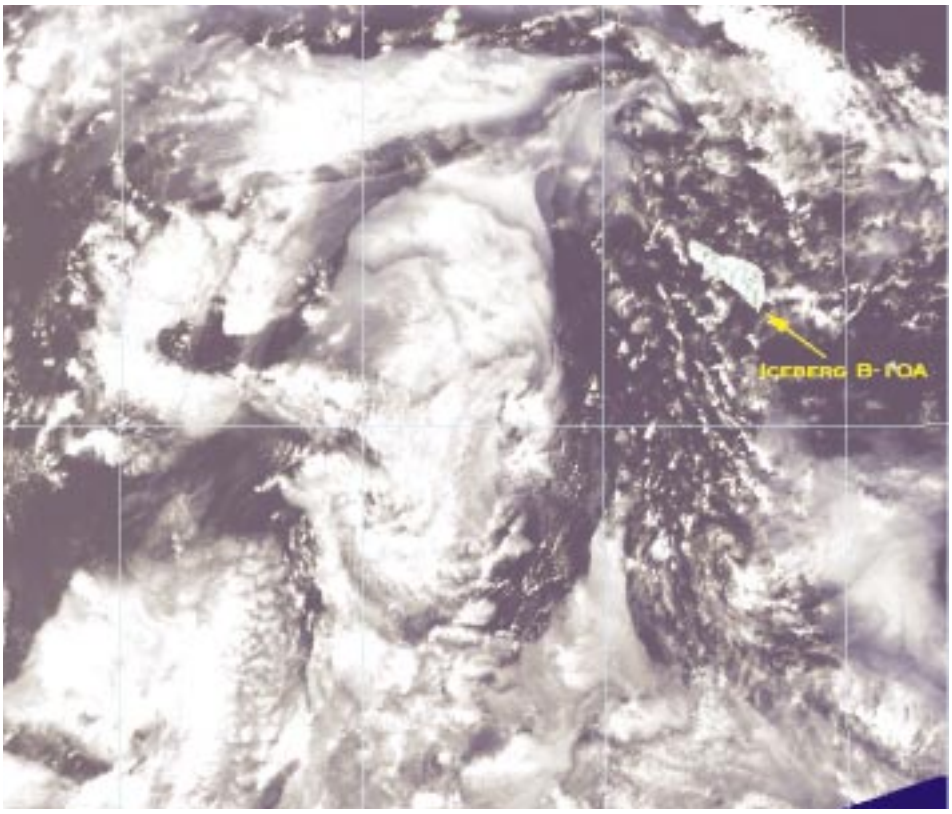


Figure 3-DOC-6. Iceberg B-10A is located amidst the cloud over in the Southern Ocean on January 9, 2000. Approximate location of the iceberg is 55.46S 37.35W.

knowledge-based rules to classify sea ice in RADARSAT SAR images.

Routine NIC ice guidance products include regional-scale ice maps, annotated satellite imagery, short and long-term ice forecasts, legacy ice information and ice climatology. NIC services available via special request include ship route recommendations, pre-sail ship briefings, aerial ice reconnaissance, and ship rider support. Sea ice features of most frequent interest include ice edge position, ice concentration, ice thickness, form or floe size, ice motion, areas of compression and heavy surface deformation, and the location/orientation of open water or thin ice-covered leads. Ice products are distributed via the Internet (*http://www.natice.noaa.gov*) as simple electronic charts in Graphics Interface Format (GIF), GIS-compatible coverages (ESRI ARC/INFO .e00 export format), and in the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDed (SIGRID, SIGRID-2) format. Date and time of data acquisition as well as the percentage of each data type used in all ice analyses are documented in a metadata narrative.

Another of NIC's responsibilities is oversight of the United States Interagency Arctic Buoy Program (USIABP), established in 1992 to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of eight government agencies and/or programs. These organizations include: the Naval Oceanographic Office, Office of Naval Research (ONR), NASA, National Science Foundation (NSF), and NOAA's NESDIS, OAR, and Office of Global Programs (OGP).

The Office of Research and Applications (ORA) provides guidance and direction for NESDIS research and applications activities. It coordinates the efforts of the Climate Research and Applications Division, Atmospheric Research and Applications Division, and Oceanic Research and Applications Division. These divisions conduct studies on the use of satellite data to monitor environmental characteristics and change and develop algorithms to produce satellite products for applications to operational weather and ocean analyses and prediction. Further, ORA participates in the development of new spacecraft and sensors for future systems. It also carries out a vigorous program to calibrate and validate satellite data to ensure its quality for long-term studies. Staff from these divisions also conduct a strong technology transfer program through scientific presentations, technical reports, Internet-based tutorials, and training workshops at domestic and international sites.

Polar-Orbiting Systems

The primary mission of the Polar-Orbiting Operational Environmental Satellite (POES) System is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-15 and NOAA-14.

NOAA polar satellites carry instruments to provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system, and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users. In addition to taking thermal images of the earth's surface and atmosphere, the NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

POES satellites carry four primary instrument systems: the Advanced Very High Resolution Radiometer (AVHRR); the Television Infrared Observation System (TIROS) Operational Vertical Sounder (TOVS); the Space Environment Monitor (SEM); and the Solar Backscatter Ultra-Violet Instrument (SBUV/2). The AVHRR provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, and snow and ice mapping.

NOAA-15 carries the first of a new generation of imager and sounder. The AVHRR on NOAA-15 contains a switchable Channel 3A (1.6 microns (μm)) and Channel 3B (3.7μm). NOAA-15 also carries the first Advanced-TOVS, or ATOVS. ATOVS consists of the High Resolution Infrared Radiation Sounder (HIRS/3), the Advanced Microwave Sounding Unit-A (AMSU-A), and the Advance Microwave Sounding Unit-B (AMSU-B), replacing the Microwave Sounding Unit (MSU) and the Stratospheric Sounding Unit flying on older polar-orbiting satellites. The new AMSU instruments are designed to provide

increased accuracy in temperature and humidity retrievals.

The HIRS/3 is a discrete-stepping, linescan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40km. Multi-spectral data from one visible channel (0.69µm), seven shortwave channels (3.7 to 4.6µm), and twelve longwave channels (6.5 to 15µm) are obtained from a single telescope and rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8µm. The mirror steps rapidly (<35 msec), then holds at each position while the 20 filter segments are sampled. This action takes place each 100 msec. The instantaneous field of vision (FOV) for each channel is approximately 1.4µm in the visible and shortwave IR, and 1.3µm in the longwave IR band which, from an altitude of 833km, encompasses an area of 20.3km and 18.9km in diameter, respectively, at nadir on the Earth.

Each AMSU-A instrument is composed of two separate units: (a) AMSU-A2 with two channels at 23.8 and 31.4GHz and (b) AMSU-A1 with twelve channels in the range of 50.3 to 57.3GHz and one channel at 89.0GHz. The AMSU-B has five channels with frequencies centered on 89, 150, 183±1, 183±3, and 183±7Ghz, respectively. AMSU-B, provided by the United Kingdom Meteorological Office, produces soundings of humidity from the surface to 200 millibars (mb). AMSU-A has a nominal FOV of 3.3 degrees (48km on surface at nadir) and AMSU-B a field of view of 1.1 degrees (16km on surface at nadir). AMSU-A (AMSU-B) samples 30 degrees (90) Earth views, covering ±48.95 degrees from the sub-satellite point. In addition, the specialized 89GHz channel, with the capability to "see" through high and mid-level clouds to low level moisture clouds, is utilized to determine the position and structure of tropical cyclones on a global scale. The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42km, or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

The SEM measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitude. The two sensors included within this instrument are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites.

In addition to the three instrument systems previously described, the "afternoon" POES carry the SBUV/2. SBUV/2 is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth. The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems: the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, CDA stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland. PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDA's to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location, calibration, and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions which are disseminated to users throughout the world.

The POES Data Collection (and location) System (DCS) is provided through an international cooperative agreement with the Centre Nationale d'Etudes Spatiales of France and is called the ARGOS DCS. The system provides a means to locate and collect environmental data from fixed and moving platforms; i.e., polar ice flows, ocean buoys, oil pipelines, birds, mammals, etc. The ARGOS DCS supports environmental applications, e.g. meteorology, oceanography, and protection of the environment, with the majority of users being government/non-profit agencies and researchers. An instrument upgrade to incorporate a downlink message capability is planned for the NOAA-N' satellite.

Geostationary Satellite Program

Two operational geostationary satellites, GOES-8 (75°W) and GOES-10 (135°W), provide coverage of virtually the entire western hemisphere for oper-

ational meteorological services. The projected launch schedule and associated instruments for geostationary satellites are shown in Table 3.1.

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9µm and 12.0µm wavelengths. However, beginning with GOES-M, the 12.0µm channel will be replaced with a 13.0µm channel, with the goal of achieving more accurate cloud height assignments for mid- and upper-level atmospheric wind-velocity estimates.

GOES satellites transmit all five spectral bands simultaneously, providing the user community with continuous views of atmospheric measurements in various wavelengths, each with its own meteorological and hydrological application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled. For example, the full-earth disk is normally scanned once every 3 hours and requires about 30 minutes to complete the entire scan. Depending on requirements to monitor environmental hazards on the Earth's surface or in the atmosphere, 30-minute periods in between the full-disk scans may be scheduled as a mixture of 15-minute intervals (routine operations) or 7½-minute interval (severe operations) scans over the contiguous United States. To further support mesoscale and microscale analyses, 1000 km x 1000 km areas can also be scanned at 1-minute intervals, to capture rapidly developing and dynamic environmental phenomena. The five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55µm to .75µm) - 1 km
- Channel 2 (Infrared, 3.8µm to 4.0µm) - 4 km
- Channel 3 (Water Vapor, 6.5µm to 7.0µm) - 8 km (4 km starting with GOES-M)
- Channel 4 (Infrared, 10.2µm to 11.2µm) - 4 km
- Channel 5 (Infrared, 11.5µm to 12.5µm) - 4 km

The GOES-8 and GOES-10 sounder instruments, consisting of 19 spectral channels, are used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index - a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverages, such as full-Earth imagery, sectorized imagery, and local imagery. In routine operations, GOES-8 and GOES-10 provide hourly sounding coverage.

The GOES Space Environment Monitor (SEM) collects data for warnings of solar activity. This block of instruments is more extensive than on POES. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on-line via Internet and on a variety of computer media.

GOES also carries a Data Collection System (DCS) which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide guages, seismometers, buoys, ships, and automatic weather stations. In support of NOAA missions, GOES DCS data are used in weather forecasts and warnings, reservoir control, and flood monitoring. While the GOES DCS is a critical element for national and international meteorological and hydrological programs, the NWS NEXRAD program relies on the DCS data as a vital input for calibration and validation. Tsunami watches and warnings for the Pacific Ocean are prepared using the Data Collection Platform data transmitted via GOES DCS. The GOES DCS program touches all aspects of our lives in supporting water quality, air pollution, and global environmental monitoring.

The GOES Search and Rescue Satellite Aided Tracking (SARSAT) System is capable of providing an immediate distress alert, unlike the POES satellite SARSAT transponders which must come within line of site of either of a Local User Terminal, in order to relay the distress beacon back to the United States SARSAT Mission Control Center (USMCC). Newer state-of-the art COSPAS-SARSAT distress beacons, utilizing the Global Positioning System (GPS), now have the capability to provide location information in the distress message relayed by GOES to the USMCC.

NESDIS continues to improve user access to its operational satellite products and services using new communications technologies including the Internet. One important on-line access system, managed and operated by OSDPD and NOAA's National Climatic Data Center (NCDC), is the NOAA Operational Satellite Active Archive (SAA). The SAA (*www.saa.noaa.gov*) provides satellite data access, display, and electronic transfer. Available data types include AVHRR, ATOVS, DMSP (special sensor), and RADARSAT (authorized subscription users). While developed as an independent system, the SAA serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). After the phase-out of the GOES-TAP system in 1998, many users now rely on GOES sector images, mapped to standard AWIPS grids, available in near real-time, at *www.goes.noaa.gov*. Finally, special

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA L	CY 2000
NOAA M	CY 2001
METOP-1	CY 2003
NOAA-N	CY 2003
NOAA-N'	CY 2008
METOP-2	CY 2008
METOP-3	CY 2012
NPOESS-3	CY 2014
NPOESS-4	CY 2016
NPOESS-5	CY 2018

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES M	CY 2001
GOES N	CY 2002
GOES O	CY 2005
GOES P	CY 2007
GOES Q	CY 2010
GOES-R	CY 2012

*Launch date depends on performance of prior spacecraft and is subject to change.

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

AVHRR - Advanced Very High Resolution Radiometer
SEM - Space Environment Monitor
SBUV - Solar Backscatter Ultraviolet Instrument (NOAA PM mission only)
HIRS - High Resolution Infrared Sounder
DCS ARGOS - Data Collection System
AMSU-A - Advanced Microwave Sounding Unit-A
AMSU-B - Advanced Microwave Sounding Unit-B
SARP - Search and Rescue Processor
SARR - Search and Rescue Repeater
MHS - Microwave Humidity Sounder (NOAA-N/N' and METOP)

Instruments for NPOESS Series

VIIRS - Visible/Infrared Imager/Radiometer Suite
CMIS - Conical Microwave Imager/Sounder
CrIS - Cross-track Infrared Sounder
ATMS - Advanced Technology Microwave Sounder
OMPS - Ozone Mapper/Profiler Suite
SES - Space Environment Suite
DCS - Data Collection System
SARSAT - Search and Rescue Satellite Aided Tracking System
ERBS - Earth Radiation Budget Sensor
TSIS - Total Solar Irradiance Sensor
ALT - Altimeter (Dual Frequency radar altimeter)

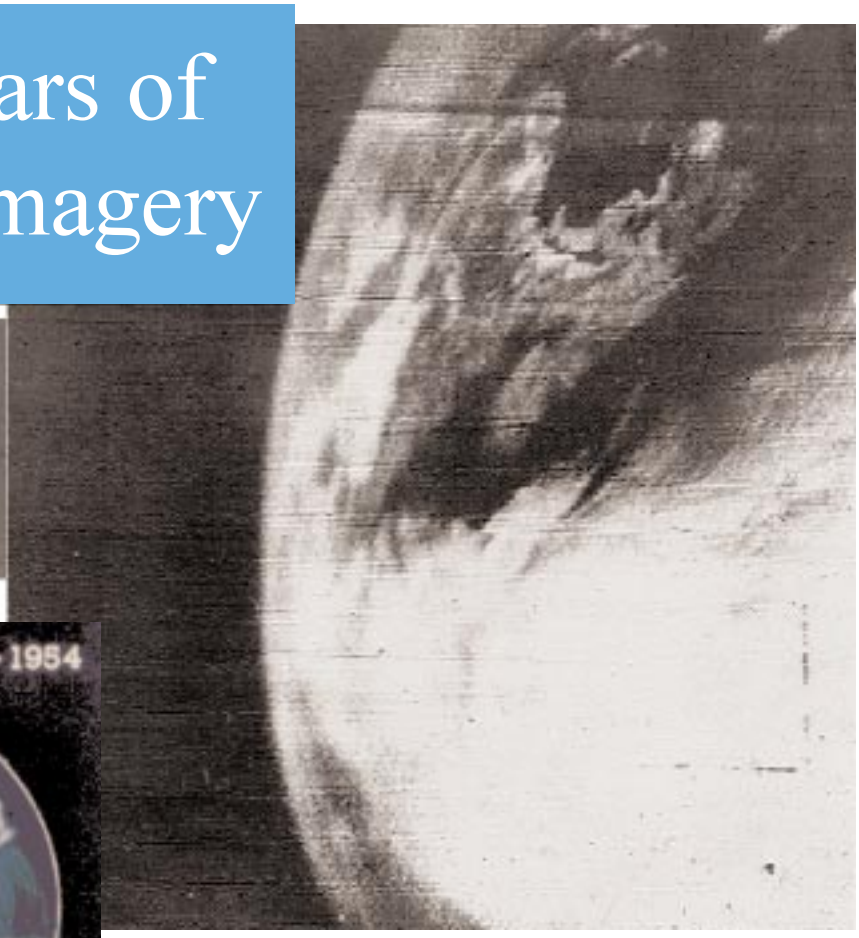
Instruments for GOES-Next Series

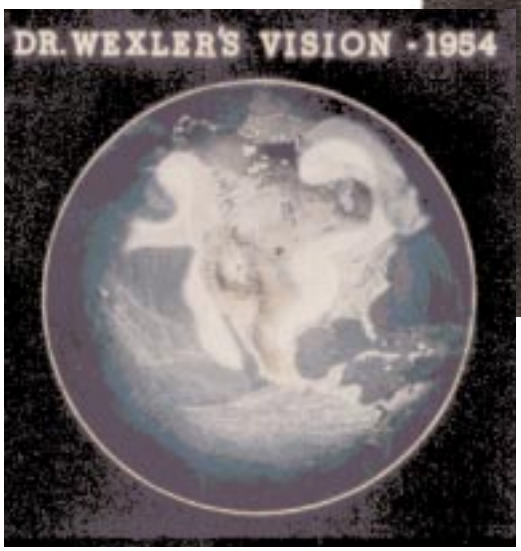
Imager
Sounder
SEM - Space Environment Monitor
SXI - Solar X-Ray Imager (GOES M and N)

EUMETSAT Unique Instruments for METOP Series Satellites

ASCAT - Advanced Scatterometer
GOME - Global Ozone Monitoring Experiment
GRAS - GPS Receiver for Atmospheric Sounding
IASI - Infra-red Atmospheric Sounding Interferometer

Forty years of Satellite Imagery





TIROS I on April 1, 1960
First TV image from space

First complete view of the world's weather by TIROS IX on February 13, 1965

events of natural disasters, including floods, hurricanes, other severe storms, volcanoes, and fires, specifically enhanced and annotated for use by the news media, federal, state, and international governments and agencies, are available from the Operational Significant Events Imagery (OSEI) server (*www.osei.noaa.gov*) (See Figure 3-DOC-5).

INTERNATIONAL SUPPORT FOR HAZARD MITIGATION

The Committee on Earth Observation Satellites (CEOS) was formed in 1984, in response to recommendations from the Economic Summit of Industrialized Nations Working Group on Growth, Technology, and Employment's Panel of Experts on Satellite Remote Sensing. This group recognized the multi-disciplinary nature of satellite-based Earth Observation (EO) data and the value of coordination across all proposed missions. In CEOS, providers and users of EO satellite data work together to promote the effective use of data from such satellites. Recognizing the benefits that could be gained from better application of EO satellite data to natural and technological hazards, CEOS initiated an activity on disaster management support. The Director of NESDIS/OSDPD chairs the group. The Disaster Management Support Group focuses on developing and refining recommendations for the application of satellite data to selected hazard areas. Particular emphasis is placed on working closely with space agencies, international and regional organizations, and commercial organizations on the implementation of these recommendations.

The Disaster Management Support Group began as a project in 1997 with an objective to support natural and technological disaster management on a worldwide basis by fostering improved utilization of existing and planned Earth observation satellite data. Meetings are held two to three times per year. Hazards addressed include drought, earthquake, fire, flooding, landslides, oil spill, sea ice, and volcanic hazards. Teams were charged with compiling user requirements; identifying shortcomings and gaps in the provision of required satellite data; and developing recommendations for alleviating them. Hazard team reports are included in the Group's annual progress reports. The latest annual progress report is available in hardcopy or via the group's web site (*disaster.ceos.org*).

SUPPORTING RESEARCH PROGRAMS

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP/EMC and other major International NWP Centers, require higher quality satellite derived winds, particularly over the traditionally data void oceanic regions of the globe. In 1998, NESDIS implemented an upgraded operational wind production suite which provides higher quality imager-based cloud-drift and water vapor motion winds at significantly increased spatial and temporal resolution. The system is totally automated and uses a series of geostationary satellite images to derive wind estimates. Automated quality control of image registration is an important component of the NESDIS GOES winds processing suite. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. With increased computer resources, a ten-fold increase in the yield of "good" wind vectors for GOES-8 and GOES-10 are being generated every 3 hours for the Northern and Southern Hemisphere. Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to EMC and to the Global Telecommunications System (GTS). EMC uses these operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems. NESDIS recently completed the effort to reformat the winds in WMO-sanctioned BUFR format. Current work involves the investigation of a slow bias seen in water vapor winds.

The newest satellite wind products include the low level high density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower-tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region which is an important area in assessing storm motion. The GOES satellites have an atmospheric sounder that includes two water vapor channels centered at 7.0µm and 7.3µm. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0µm channel peaks around 450mb and the weighting function of the 7.3µm channel peaks around 550mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in 1999. These wind products can be viewed at *orbit-net.nesdis.noaa.gov/goes* and *cimss.ssec.wisc.edu/tropic/real-time.*

Atmospheric Moisture and Stability Products

Research continues to improve the atmospheric moisture and stability products from the GOES-8 and GOES-10 sounder instruments. Precipitable water for three layers of the atmosphere: surface to 900 hPa; 900-700 hPa; and 700-300 hPa are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the earth's surface to the "top" of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation, locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this information provide useful information for the EMC regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to ETA Data Assimilation System (EDAS) which provides the initialization for the ETA forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes. At present, a blended GOES, SSM/I, and model-derived product is being evaluated. In addition, a precipitable water product has been developed from the NOAA-15 AMSU sensor, and is presently undergoing evaluation. In the near future, the blended product will include the AMSU-derived precipitable water. In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events. So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field, for example, to understand the time evolution of severe storms. It was anticipated that the GOES sounder moisture and stability products which presently have a horizontal resolution of approximately 50 km^2, would be generated at a high horizontal resolution of 30 km^2 by the summer of 2000. These products can be viewed at *orbit-net.nesdis.noaa.gov/goes* and *cimss.ssec.wisc.edu*. A similar suite of products is being developed from NOAA-14 and NOAA-15 for forecasters.

Precipitation Estimates

The Auto-Estimator produces quarter-hourly estimates of precipitation based on GOES infrared data. This technique was devised to replace the more manual "Interactive Flash Flood Analyzer" (IFFA). The Auto-Estimator has an orographic adjustment factor and can be manually adjusted for warm cloud tops. Current improvements being tested include using: RADAR and visible data (as a rain/no-rain detector) and equilibrium level temperatures from the ETA model for warm top adjustments. Other techniques are being tested such as the GOES Multi-Spectral Rainfall Algorithm (GMSRA), a combined GOES and SSM/I rainfall algorithm (developed at NRL/Monterey), and a NOAA-15 AMSU based retrieval algorithm. The GMSRA uses all five GOES imager channels and may be merged with the Auto-Estimator after the intercomparison is completed. Finally, the POES based microwave algorithms from the SSM/I and AMSU sensors are being utilized to produce automated tropical cyclone rainfall potential estimates and global precipitation estimates are produced from microwave data for climate monitoring and analysis. These products can be viewed at: *orbit-net.nesdis.noaa.gov/arad/ht* and *manati.wwb.noaa.gov/doc/ssmiprecip.html*

Microburst Products

Several experimental microburst and convective wind gust products are being tested. These products utilize sounder data from both GOES-East/West to compute the maximum possible wind gust and the potential for both wet and dry microbursts over the continental United States. They are produced hourly during the convective season and can be viewed at *orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html*

Low Cloud and Aircraft Icing Products

Detection of fog and low clouds, particularly at night, is important to aviation activities. A GOES product utilizing two infrared channels (10.7mm and 3.9mm) can help determine the areal extent of this cloudiness at night over the continental United States and Alaska every 30 minutes. An experimental fog depth image is produced hourly. An experimental cloud base height product for the West Coast was added in 2000 to estimate low ceilings (< 1,000 ft) that are critical to aviation operations. Fog products can be found at *orbit-net.nesdis.noaa.gov/arad/fpdt/fog.html*. By combining information from the visible and longwave infrared (12.0mm) channels to the two described above, areas of possible aircraft icing can be delineated. The icing product is available hourly and can be viewed at *orbit-net.nesdis.noaa.gov/arad/fpdt/icg.html.*

Geostationary Sea Surface Temperatures

GOES-8 and GOES-10 are proving capable of producing sea surface temperatures (SST) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the GOES measurements are close to that achieved from the polar orbiting platforms, and GOES has a unique advantage of high temporal sampling frequency. For the

SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Cloud detection is enhanced by noting that a change in scene temperature over a short period of time may indicate the presence of clouds. The abundance of GOES observations helps to maintain a balance between high-quality, cloud-free observations and good geographical coverage of SST estimates. For the first time, GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long time periods. This quantification may have important implications in both numerical weather prediction and climate monitoring. NESDIS has been producing the GOES SST hourly since December 1998 for both GOES-8 and GOES-10 and had planned to declare the product operational by June 2000. A global SST product is produced every three hours; regional SST products are generated every hour. These products were planned for operational implementation in 2000.

Volcanic Ash Monitoring

Techniques that use the imager and sounder channels on GOES-East/West are being developed to assist in the tracking of volcanic ash cloud plumes (Figure 3-DOC-7). One product that employs three channels (10.7µm, 12.0µm, and 3.9µm) has been developed and is under evaluation. Ash cloud advisory statements are provided by NESDIS to the aviation community over southern North America and northern South America, through the Volcanic Ash Advisory Center in Washington, District of Columbia. The experimental volcanic ash product is produced hourly for several active volcanic areas and made available on the Web at *orbit-net.nesdis.noaa.gov/arad/fpdt/volc.html*.

Fire and Smoke Monitoring Algorithms are being developed to detect fires and to monitor their growth and the associated smoke coverage. The GOES-8 split window data (at 4µm and 11µm) have been used to assess trends in South American burning practices over the past 6 years (1995-2000); GOES detected the most fire pixels in the tropical rain forest ecosystem in 1995. The application to clear sky human-initiated burning in South and Central America is now being adapted to monitor cloudy sky lightning and clear sky human-initiated fires in the Canadian provinces and the continental United States. The continual monitoring from GOES (as often as every 7½ minutes) can assist firefighters to plan evacuation and extinguishing activities. NESDIS planned to test the routine production of a fire product in the summer of 2000. Studies with Brazil are underway to predict smoke transport and air pollution and health alerts for major cities. An AVHRR fire detection algorithm is being developed for use in monitoring fire and smoke outbreaks around the world. This algorithm is being implemented in a Hazard Mapping System that will provide analysts a means to look at fire and smoke events as well as other environmental hazards, and provide the data to users and the media.

A GOES Products and Services Catalog is available on line at *orbit-net.nesdis.noaa.gov/arad/fpdt/goescat/index.html*. An up-to-date list and description of operational and experimental products with links to the real-time products are available from this web page. A Polar Products and Services Catalog is under development and is planned for 2001.

NPOESS

ORA scientists continue to play an important role in the evaluation of proposed contractor sensor design and retrieval methods during the ongoing selection process for NPOESS. ORA scientists have created a variety of "test bed" data sets that are being used in the algorithm evaluation process. This is accomplished through participation in operational algorithm teams with the long-term goals of assuring capability to meet the requirements of all Environmental Data Records. Ozone evaluation, calibration, and validation activities will take place for the new

Figure 3-DOC-7. Strong heat signature (red) and an ash plume associated with eruptions of Mount Etna volcano in northeastern Sicily. Other visible hot spots in image are probably due to wildfires.

Solar Backscatter Ultraviolet Instrument (SBUV/2) instrument after the launch and successful checkout of NOAA-L. A new ozone profile retrieval algorithm (Version 7) is under development at NASA. As soon as it becomes available, NOAA will begin to incorporate it in its SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-11, -14, and -L, and with the TOVS instruments on NOAA-14, -15 and -L. Experimental high temporal ozone products are also being produced from the GOES-8 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

Land Surface Parameters for Use in Weather Forecast Models

Satellite-derived fields of land surface characteristics are being prepared for use in NWP models. These include radiation products delivered in near real-time as forcing variables, surface characteristics, such as fractional green vegetation and albedo, that specify model lower boundary conditions and validation quantities, such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts, and better precipitation forecasts. These fields now include POES-based (SSM/I and AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness. Development of snow depth is underway. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models. Algorithms to determine clear sky ice surface temperatures have been developed and delivered to Atmospheric Environmental Services, Canada for evaluation.

Clouds from AVHRR

Algorithms are being developed, tested, and validated for determining cloud optical and microphysical properties from imager data such as the AVHRR. These algorithms are in addition to those already developed which estimate amounts and types for each observed cloud layer. The four cloud types are: L - Liquid Water Clouds; M - Mixed Phase Clouds; G - Glaciated Clouds (opaque); and H - High Ice Clouds (semi-transparent). Knowledge of cloud properties is important for both climate-scale and short-medium range forecasts. Accordingly, algorithms and processing systems to estimate cloud properties from imager data are being developed for both applications. Assimilation of cloud properties into NWP models is an objective of NCEP for improving short-medium range forecasts. Other applications of this work include the validation of simulated scenes to be used for evaluation of new algorithm and instrument designs which is supported by the IPO. In addition, new algorithms are being developed to produce optimal estimates of cloud properties from both imager and sounder data, such as the merge of AVHRR and TOVS data.

Aerosols

An algorithm for the correction of a thermal radiation leak in the 1.6μm reflectance channel of the Tropical Rainfall Measuring Mission (TRMM) satellite's Visible Infrared Scanner (VIRS) has been developed. It is being applied to VIRS raw data prior to application of the NESDIS operational aerosol retrieval algorithm by NASA's Clouds from the Earth's Radiant Energy System (CERES) instrument data processing team. Without this correction, the aerosol optical thickness at 1.6μm would be overestimated by as much as 200 percent, depending on the temperature of the Earth's surface. In FY 2001, we will validate retrievals of aerosol optical thickness (AOT) and the Angstrom Exponent, a measure of the size of particles in the atmospheric column derived from optical thickness measurements at 1.6μm, and 0.63μm, the other reflectance channel of VIRS. Validation will be accomplished by comparison with sun-photometer measurements of solar extinction at five wavelengths from 15 island and coastal locations established by NASA's Aerosol Robotic Network (AERONET). This algorithm will also be applied to NOAA-L AVHRR data (after its launch) which has the same two reflectance channels as VIRS plus an 0.83μm reflectance channel. This information on aerosols will be used to correct for the attenuation of aerosol particles in the infrared channels of the AVHRR instrument to remove errors in the retrieval of sea surface temperature. The correction algorithm will initially be derived from the multi-year archive from the AVHRR Pathfinder Atmosphere (PATMOS) data set using a single channel AOT retrieval at 0.63μm. The long-term record of AVHRR SSTs can be corrected for aerosol induced errors which currently limit the utility of these data for climate change studies. Finally, an algorithm for the estimation of aerosol optical thickness over dark vegetated land surfaces will be developed in support of NASA's Global Aerosol Climatology Project (GACP). It will also utilize the PATMOS archive of clear-sky reflectances at 0.63μm collocated with sun-photometer observations of AOT at non-coastal land based AERONET stations to make empirical adjustments to the surface reflectance model used in the NESDIS operational aerosol retrieval algorithm used over oceans. This will be the first globally applicable aerosol retrieval algorithm for land areas and will be used by NASA and NOAA to create a climatology of aerosol optical thickness over land for climate change studies.

Long-term Monitoring of NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) Performance

Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the CEMSCS and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated from the AMSU-A 1B data. NESDIS has already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications and, in some channels, it is lower than estimates based on pre-launch test results. In FY 2001, NOAA will examine the other radiometric parameters. NOAA will also continue compiling long-term trends of all the parameters to provide a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

Calibration of the Visible and Near-Infrared Channels of the AVHRR

The AVHRR flown on POES is recognized as an invaluable resource for satellite-based studies of the Earth system. The long-term records of geophysical products such as the Normalized Difference Vegetation Index (NDVI), columnar aerosols over the oceans, cloud morphology, and short-wave radiation budget play a central role in climate and global change studies by providing a means to study the environment continuously. It is thus very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of the AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible (Channel 1: 0.58 - 0.68 µm), and near-infrared (Channel 2: 0.72 - 1.1 µm; Channel 3A: 1.58 - 1.64 µm) channels which do not have any onboard calibration devices. The major program elements are: (a) development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by the AVHRR and by calibrated spectrometers onboard aircraft; (b) enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond ± 5 percent; (c) evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors, in general, using radiometers on the ISS traceable to the National Institute of Standards and Technology (NIST); (d) establishment of the AVHRR as a traveling calibration standard to monitor the performance of sensors, such as the imager on the GOES, the visible channel of the High-resolution Infrared Radiation Sounder (HIRS), the Moderate-resolution Imaging Spectrometer (MODIS), and various sensors to be flown on ENVISAT; and (e) design of optimal onboard and vicarious calibration techniques for the visible and near-infrared sensors planned under the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The relevance and importance of these activities has been recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV), Committee on Earth Observation Satellites (CEOS), and the Global Observing Systems Space Panel (GOSSP). To ensure global access to the results of the above program, and recognizing the importance of the AVHRR-derived products to national and international programs, such as the International Satellite Cloud Climatology Project (ISCCP), the International Geosphere Biosphere Programme (IGBP), the Global Climate, Ocean, and Terrestrial Observing Systems, and to benefit from sensor calibration research elsewhere, active liaison, and collaboration in some instances, has been established with researchers in NASA, NIST, EUMETSAT, China Meteorological Administration, Beijing, China; Rutherford Appleton Laboratory, United Kingdom; National Space Development Agency, Japan; the NOAA/NASA Pathfinder Program; several space agencies and remote sensing laboratories outside the United States, and academia both in the United States and abroad. Accomplishments to date include near real-time updating of the calibration of the AVHRR on NOAA-14; determination of the in-orbit degradation of the AVHRR on NOAA-15 within six weeks after launch, and the evaluation of the performance of the visible channel of HIRS on NOAA-14, using the AVHRR as a calibration standard. Dissemination of the information resulting from the calibration activity is accomplished through presentations at the meetings of learned and professional societies, publications in the literature, and through the electronic media.

Calibration of Geostationary Operational Environmental Satellite Instruments

The wavelength configuration of channels on the Geostationary Operational Environmental Satellite-M (GOES-M) Imager will be slightly different from that of its predecessors. The current 12µm channel will be replaced by one at 13.3µm. The new channel will employ a single detector with an 8-km field-of-view at the Earth's surface. The water-vapor channel at 6.7µm, which on GOES I through L observes the Earth with a single 8-km detector, will employ two

4-km detectors on GOES-M. To accommodate these revisions, the calibration processing in the ground system will be modified.

Pathfinder

Climate data sets of cloud amount, aerosol optical thickness (AOT) over the oceans, and the Earth's radiation budget for clear and cloudy skies have been retrospectively generated from over 17 years of AVHRR data as part of the NOAA-NASA Pathfinder program. An improved data set spanning the period from July 1981 through the end of 1999 was completed in 2000. This data set is being utilized to study the relationship between the variation in global mean values of the absorbed solar radiation and variation in aerosol amount caused by major volcanic eruptions. The influence of the aerosol amount on variations in the global surface temperature is also under investigation. Analysis of time series of anomalies of the cloud radiative forcing have been shown to correlate well (spatially and temporarily) with El Niño events. A second reprocessing of the entire data set is being proposed, where multiple-layered cloud data will be used. Land surface and ocean products such as the vegetation index and the sea surface temperature will be added.

Ocean Surface Winds

Calibration and validation studies are performed for all new operational ocean surface wind data streams. Product refinement and development activities are currently underway to improve ocean wind vector retrievals in the high wind speed regime where current retrieval algorithms underestimate the wind speeds. There are several satellite-based active and passive microwave sensors planned for launch in the near future that NOAA will have the opportunity to obtain near real-time data streams from. One of these sensors will be the first demonstration of the passive polarimetric technique, which is the technique that is being depended on for NPOESS to meet the nation's ocean surface wind vector requirements.

Storm Signatures and Winds from Synthetic Aperture Radar

ORA scientists are currently studying ocean surface wind signatures of atmospheric fronts and storms with synthetic aperture radar (SAR) imagery. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as coastal lee waves), atmospheric fronts, and coastal wind shadowing. Techniques for calculating wind speed (and under certain conditions direction as well) are also under development. A near real-time demonstration of SAR applications in Alaska was conducted in the fall of 1999 using data from the Canadian RADARSAT satellite. SAR images of the Bering Sea and northern Gulf of Alaska were provided to the NWS Anchorage WFO for analysis of wind conditions, location of polar lows, and position of the ice edge. Wind speed images derived from SAR were also provided along with other wind data from scatterometer winds to allow meteorologists at the Anchorage office to assess the utility of SAR data and derived products to their operational weather analysis and forecast activities. Before the year 2003, four new wide-swath SAR satellites are planned for launch. If data acquisition and sharing arrangements can be made to obtain access to SAR imagery from these new sources, frequent routine SAR coverage of United States coastal areas will be possible.

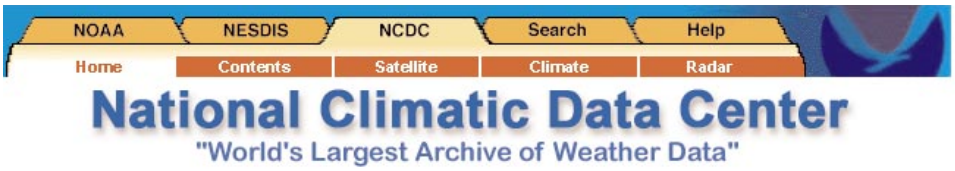
Ocean Color

Several programs at ORA are involved in satellite ocean color research. The Marine Optical Buoy (MOBY) Project develops, deploys,and maintains the MOBY off of the coast of Lanai, Hawaii, to measure visible and near-infrared radiation entering and emanating from the ocean. The resulting measurements support the initialization and vicarious calibration of international and national ocean color sensors, such as the Ocean Color and Temperature Sensor, the Sea-Viewing Wide-Field-of-View Sensor, and the recently launched Moderate Resolution Imaging Spectroradiometer. The Marine Optical Characterization Experiment (MOCE), MOBY's sister project, involves the collection of insitu measurements of these and other parameters relevant to ocean color in the surrounding region from ship. Data from both sampling platforms furnish a time-series of bio-optical measurements that is employed to track sensor drift, define bio-optical relationships, validate satellite-derived products, and develop ocean color algorithms. In addition to MOBY and MOCE, programs exist at ORA to routinely evaluate the accuracy of NESDIS operational ocean color products and to develop algorithms in order to remotely detect and predict the presence of noxious marine biota, such as harmful algal blooms.

Coral Reef Watch: NOAA's Early Warning System for Coral Reef Health

Like the rest of the world, most of the United States coral reef systems are threatened due to pollution, over-fishing, and thermal bleaching. This threat includes almost all of Florida and Puerto Rico reefs, nearly half of Hawaii's, and an unknown but significant fraction of United States Pacific Territories. The widely-distributed and isolated location of many coral reefs preclude normal monitoring practices. In 1998, NESDIS established an experimental capability using POES satellites to conduct thermal bleaching surveillance of coral reefs on a worldwide basis. This experiment demonstrated remarkably accurate capabilities for early warning of El Niño-induced coral reef bleaching conditions over all global tropical ocean regions resulting in a special International Workshop on Satellite

Monitoring of Coral Reefs being convened in June 1999. A Coral Reef Watch Program was proposed to (1) transition existing experimental satellite reef health monitoring capabilities into a viable operational capability, (2) formalize the existing United States leadership in the emerging global" Virtual Coral Reef Ecosystem Monitoring Laboratory," and (3) provide for a solid scientific basis for future monitoring and assessment products/capabilities.



ENVIRONMENTAL DATA CENTERS

National Climatic Data Center (NCDC)

NCDC has the responsibility for long term stewardship and access to the Nation's climatological data. To meet this responsibility:

- NCDC performs data management and access functions regarding retrospective meteorological data, including data from *in situ* (ASOS, AWOS, Rawinsonde, COOP, etc.)and remote sensing sources (satellites, radars, etc.). Such functions include: acquisition (ingest, to include inventories), quality control processing, archiving, access, indexing, quality assessment, evaluation, synthesis, and dissemination of data collected by global and national meteorological observation networks or systems. Meteorological data that have enduring value to the Nation and are sufficient to describe the climate are included.
- NCDC serves as the Nation's official Data Center for Climatological Data, as such part of the Federal Records Retention System (FRRS). Follows NARA guidelines and policies for meteorological data records and information.
- NCDC partners nationally with National Aeronautical and Space Administration (NASA), Department of Defense (DOS), Environmental Protection Agency (EPA), Department of Agriculture (USDA), Department of Energy (DOE), Department of State (DOS), National Science Foundation (NSF), Geological Survey (USGS), Global Climate Research Panel (USGCRP), and others.
- NCDC partners internationally with: World Meteorological Organization, International Council for Science, World Data Centers, Bilateral Agreements, Intergovernmental Panel on Climate Change, UNESCO.
- NCDC maintains national and global baseline data sets for analyses of long-term climate trends and for monitoring global change i.e. Global Historical Climatology Network (GHCN), United States Historical Climatology Network (USHCN), Comprehensive Ocean-Atmosphere Data Set (COADS), and Comprehensive Aerological Reference Data Set (CARDS).
- NCDC serves as the World Data Center for Meteorology at Asheville, under the auspices of the International Council for Science. In this capacity, NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries.
- NCDC provides facilities, data processing support, data exchange, and expertise, as required, to meet United States commitments to foreign nations, international organizations, and to WMO programs.
- NCDC is one of the archive locations for the NCEP/NCAR Re-analysis data set. NCDC will supplement what other agencies (NCEP/CEP and ERL/CDC) have done in making portions of this data set available on-line. NCDC will place the Re-analysis model input data on-line.
- NCDC manages the Regional Climate Center (RCC) Program consisting of six facilities. These Centers, located at universities or state agencies, provide data collection, user services, and applied climate research on a regional basis. NCDC also coordinates the State Climatologist (SC) programs. Along with the NCDC, the RCCs and the State Climatologists form the national climate services program.

National Oceanographic Data Center

The National Oceanographic Data Center (NODC) supports climatic services and research through its data management and data services activities. NODC provides data management for major climate-related studies, such as the TOGA program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). NODC performs a number of functions for the Global Temperature Salinity Profile Program (GTSPP), including incorporation of real-time and delayed mode data into a continuously managed data base. GTSPP makes global temperature and salinity data quickly and easily accessible to users. NODC also provides data products and services individually to researchers as well as to members of the operational marine community, e.g., the Navy, Coast Guard, and shipping industry. NODC distributes on CD-ROM the Atlas of Surface Marine Data, which includes global surface marine observations, taken from COADS files. It also includes objectively gridded fields of surface marine fluxes of heat, momentum, and fresh-

water. NODC also archives and distributes on CD-ROM surface marine data collected by NOAA's Coastal - Marine Automated Network (C-MAN) stations, and NOAA moored buoys. Both products are described on NODC web pages, and made available through the NOAA National Data Centers' (NNDC) Online Store.

National Geophysical Data Center

The National Geophysical Data Center (NGDC) manages geophysical data and information resources for NOAA and the scientific community within the disciplines of solar-terrestrial physics, paleoclimatology, snow and ice, marine geology and geophysics, and solid earth geophysics. NGDC participates in national and international programs that collect and provide data for research in meteorology, climatology, and space weather. NGDC operates World Data Centers for Solar-Terrestrial Physics, Paleoclimatology, Marine Geology and Geophysics, Solid Earth Geophysics, and Snow and Ice under the auspices of the International Council for Science. NGDC operates the secretariat for the Scientific Committee for Solar-Terrestrial Physics.

NGDC provides data processing, access, management, archive, analysis, research and stewardship services for space weather, paleoclimatological, cryospheric, and some meteorological databases collected on satellites and by ground-based observatories. Space environment data collected on GOES and POES satellites and space environmental, meteorological and oceanographic data collected on DMSP satellites are officially archived by the Solar-Terrestrial Physics Division. Ground-based measurements of solar activity, ionospheric structure and geomagnetic variations used in space weather forecasts, warnings and alerts are archived at NGDC. The Paleoclimatology Group operates NOAA's Paleoclimatology Program, which manages geophysical data used to derive paleoclimate data and information. Cryospheric data from ground-based and satellite instruments are managed by the National Snow and Ice Center, which is affiliated with NGDC.

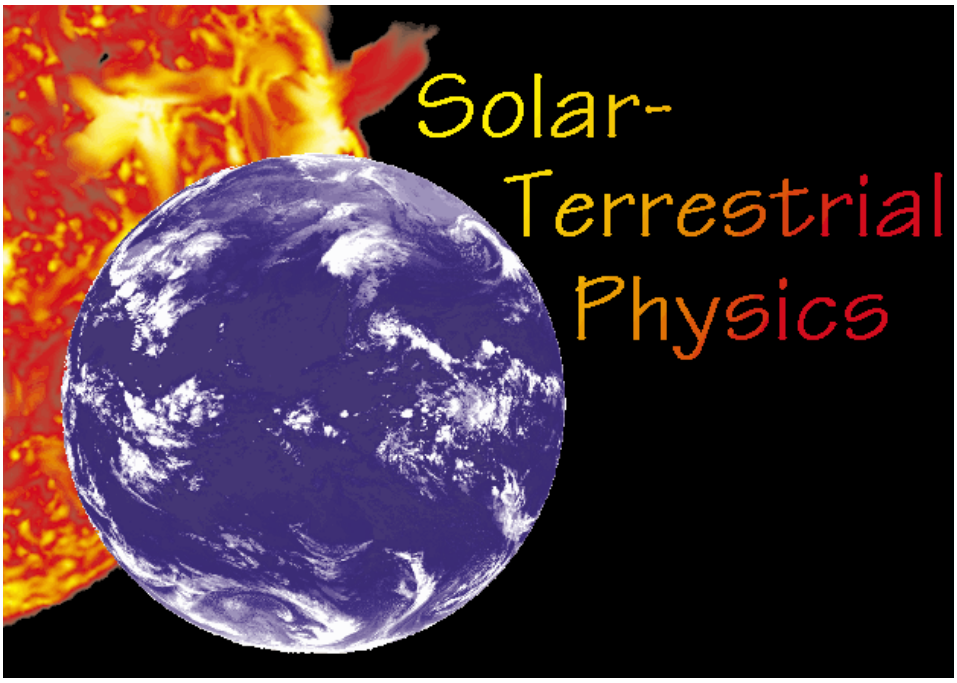
New technology presents new opportunities and challenges for NNDC and the World Data Center system. NGDC uses WWW-based applications to provide improved, more timely services including data discovery, automated inventories, on-line catalogs, interactive data display, data mining, and data delivery. As a result, the number of users has increased dramatically. Since most of the new users are less familiar with the data than the research community, additional burdens are placed on the NNDC's to assure that quality data are provided in a display that is easy to understand and in a format that is easy to use. At the same time, new applications are under development, which increase the need for quality data; they are the mining of information from the data archives and the running of data-driven numerical models from remote locations (*www.ngdc.noaa.gov*).

NOAA's Defense Meteorological Satellite Program (DMSP) at NGDC prepares research quality data recorded by scientific instruments on DMSP operational satellites for retrospective analysis and the official archive. Data sets include visible, infrared and microwave imagery, microwave soundings and *in situ* measurements of the space environment. The official archive is used to prepare products, derive geophysical parameters including atmospheric and ionospheric principal components, and provide user services. New user services are provided through the Space Physics Interactive Data Resource (*www.ngdc.noaa.gov/dmsp*).

NOAA's paleoclimate program to assemble global information on paleoclimate is operated by NGDC. The program has acquired many paleoclimate databases derived from geophysical data, namely tree-rings, pollen and macrofossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Paleoclimate databases can be displayed, searched, and retrieved using custom software (*www.ngdc.noaa.gov/paleo*).

The Space Weather program at NGDC prepares research quality data of the near-Earth space environment for retrospective analysis and the official archive. GOES, DMSP, and POES satellites carry instruments that monitor the space environment; for example, the SEM instruments on GOES and POES and the SSIES, SSJ/4 and SSM instruments on DMSP. Future instruments, namely the GOES Solar X-Ray Imager and two DMSP Ultraviolet Imagers, will greatly increase both the use and volume of space sensor data. Other data sets in the space weather archives include measurements of solar activity, solar flares, magnetic activity, magnetic storms, ionospheric parameters, and ionospheric storms collected by NOAA and other agencies. The STP program has a long and successful history of cooperating with NASA, USGS, DOD, academia and other NOAA components. The STP program at NGDC

archives measurements of total solar and solar spectral irradiance for use in climate studies. The data sets are recorded on NOAA and NASA satellites and irradiance values inferred from ground-based solar imagery (*www.ngdc.noaa.gov/stp/stp. html*)



The National Snow and Ice Center(NSIDC) at the University of Colorado is associated with NGDC and maintains several cryospheric-related data sets of interest to meteorology and climatology. These data sets include a collection of historical photographs of glaciers, temperature, pressure and position data from drifting buoys placed on the central Arctic pack ice, and data from the NOAA snow cover and DOD-NOAA sea ice chart digitizing projects. NSIDC provides data management services for a variety of cryospheric research programs sponsored by NASA and NSF. In addition, NSIDC has developed gridded sea ice products (sea ice concentrations and multi-year ice fraction) based on passive microwave data collected by NASA and DMSP satellites. NSIDC is acquiring snow cover, glacier and sea ice records from the former Soviet Union. Online services are available, at *www-nsidc.colorado.edu*.

SUPPORTING RESEARCH

CLIMATOLOGY

Global Historical Climatology Network (GHCN)

The GHCN data set is a comprehensive global surface baseline climate data set designed for monitoring and detecting climate change. Comprised of surface station observations of temperature, precipitation, and pressure, all GHCN data are monthly values. Users of the NCDC web site can now view the spatial distribution of global temperature and precipitation trends and anomalies through a new interactive web page. This page can be accessed through the GHCN web page (*www.ncdc.noaa.gov/cgi-bin/res40.pl?page=ghcn.html)*.

Blended Temperature Project

A global surface temperature data set was produced from numerous sources including sea surface temperatures (SST), land surface temperatures, and satellite data using the special sensor MSU which collects data over land areas that are not snow covered. Additional coverage over snow covered areas will soon be provided via the MSU on board the TIROS weather satellite.

New Climate Atlas of the United States

The purpose of this new atlas project is to depict the climate of the United States in terms of the distribution and variation of major climatic elements. The Climate Atlas will meet the needs for climatic information from research, commercial, industrial, agricultural, educational institutions, as well as from the general public. Information contained in the atlas will be used for planning, engineering, and scheduling purposes. The new atlas when completed, should contain several hundred updated high resolution GIS generated maps.

Climate Reference Network Project

The United States Climate Reference Network (CRN) is a network of climate stations now being developed as part of a NOAA initiative. The primary goal is to provide future long-term homogeneous observations of temperature and precipitation that can be coupled to past long-term observations for the detection and attribution of present and future climate change. The CRN will also provide the United States with a reference network that meets the requirements of the Global Climate Observing System (GCOS). The stations will monitor temperature, precipitation, solar radiation, and wind speed. Hourly observations of these variables will be transmitted in real-time.

Climate Monitoring

The NCDC Climate Monitoring Group produces operational as well as special-event reports on climate and weather around the globe. These NCDC reports address the climate in historical perspective and are available via the NCDC web site. Highlights include: synopses of global monthly and annual mean temperatures and precipitation and their departures from the long term mean; global and United States extreme events; and United States and global regional analyses using traditional surface data as well as blended surface and satellite data products. The monitoring group also

responds to high level NOAA and executive level governmental requests concerning the state of the national and global climate. The products and reports address the climate in historical perspective and are available via the NCDC WWW site at *www.ncdc.noaa.gov*.

Paleoclimatology

NOAA's paleoclimate program to cooperate in research projects to use the combined global paleoclimate database for climate model verification and climate change studies is operated by NGDC. Objectives of the program are to cooperate with researchers and to conduct original research to describe the global patterns of annual-to-millennial scale climate change, to understand the causes of climate change, to separate man-induced climate change from natural variability, and to validate the models that are used to predict future climates. Support is received from the NOAA Climate and Global Change Program. More information is available at the NGDC website (*www.ngdc.noaa.gov/paleo/paleo.html*)

Environmental Remote Sensing

Operational meteorological satellite imagery provides a unique opportunity to monitor wildfires and population dynamics on global and nightly bases. NOAA's DMSP program at NGDC uses the nighttime imagery to locate sources of visible and infrared emissions including city lights, lightning, fires, flaring gas, and boats. Research projects use the city lights to infer population density, economic vitality, and carbon dioxide emissions. More information is available at the NGDC website (*www.ngdc.noaa.gov/stp/stp.html*).

Wildfires Monitored from Space

Operational meteorological satellite systems offer a unique opportunity to monitor wildfires because each satellite records infrared emissions covering the entire globe each day. An instrument designed to detect clouds also "see" fires, many of which burn in very remote areas. NGDC has developed a unique technique to capture nighttime emissions from both large and small wildfires. The system has been used to assist firefighters in developing countries. More information is available at the NGDC website (*www.ngdc.noaa.gov/dmsp/fires/globalfires.html*).

Space Weather

The Space Weather program at NGDC conducts original research in space physics with an emphasis on space weather applications. Research focused on numerical modeling of the ionosphere and magnetosphere is conducted with resident and visiting scientists from the United States and other countries. Research projects use the extensive integrated data bases archived at NGDC. In addition to building better models and improving our understanding of ionospheric and magnetospheric plasma processes, the research leads to improved data sets and new data products. NGDC has embarked on an environmental scenario generator project to mine information from the archives and to use the mined information to launch a numerical simulation of the atmospheric and space environment. More information is available at the NGDC web site (*www.ngdc.noaa.gov/stp/stp.html*).

OBSERVING SYSTEM PERFORMANCE INDICATORS

This multi-year effort will provide real-time information on the health and status of NOAA's observing networks. The developed system will continually monitor and assess the state of these networks with the intent of providing feedback that could either lead to improvements in the network or changes in analysis techniques to account for problems in the network.

OCEANIC AND ATMOSPHERIC RESEARCH LABORATORIES

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various NOAA meteorological, oceanographic, and space science missions. The activities of OAR laboratories are oriented toward providing the scientific and engineering understanding, tools, and techniques that form the basis of improved national weather and climate services.

Special emphasis is placed on improving severe weather and hurricane warnings and forecasts and on improving the utilization and dissemination of data and information. Severe weather events include flash floods, strong winds, thunderstorms (including tornadoes, lightning, and hail), heavy snowstorms, extreme cold and heat, drought, and geomagnetic storms. The key contributions to improved hurricane forecasts fall under the "Hurricanes at Landfall (HaL)" focus of the United States Weather Research Program (USWRP). They include more accurate prediction of track, intensity, surface winds, rainfall, and human impacts. In pursuit of improved utilization and dissemination of data, the OAR laboratories conduct both in-house and cooperative research with other NOAA organizations, government agencies, joint institutes, universities, and the private sector.

Observing Technology

Two OAR laboratories in Boulder, Colorado, and one in Norman, Oklahoma, are heavily involved with developing new environmental observing system technologies. The Environmental Technology Laboratory (ETL) in Boulder, Colorado, develops and evaluates new remote-sensing concepts and systems. This development and the associated environmental research directly supports the Nation's forecasting and warning services. A comprehensive view of the laboratory and its research can be found on the Web (*www.etl.noaa.gov*). The Forecast Systems Laboratory (FSL) (*www.fsl.noaa.gov*) takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers these technologies to NOAA operations and the private sector. The National Severe Storms Laboratory (NSSL) (*www.nssl.noaa.gov*) located in Norman, Oklahoma, both develops new remote sensing systems and assists in the transfer of these technologies to the NWS.

A major example of these activities is the development of the world's first major wind profiler network. An outgrowth of early basic research at NOAA's Aeronomy Laboratory and extensive development at ETL, FSL now operates a network of 30 unattended wind profiling Doppler radars that provide profiles of high resolution winds aloft to National Weather Service (NWS) forecasters and modelers, universities, government researchers, and the private sector. Radio-acoustic sounding systems (RASS) comprising integrated wind profiler radars and acoustic sources are now capable of measuring temperatures as well as winds. The NOAA Profiler Network (NPN) has made significant contributions to improved forecasts and warnings since its completion in 1992.

In a continued collaboration between NWS and FSL, three NOAA profilers were recently installed in Alaska to support NWS volcanic plume tracking and hazard mitigation. All three profilers transmit at the new operational frequency of 449-MHZ. The engineering requirements for the transition of wind profilers from an experimental frequency allocation of 404.37-MHz came from collaborative efforts between FSL, ETL, and the United States Air Force.

In another example of technology transfer, FSL is collaborating with several universities, NOAA's National Geodetic Service, the United States Coast Guard, and the Federal Highway Administration to develop and deploy a network of surface-based water vapor observing systems for NOAA that utilize the Department of Defense's Global Positioning System (GPS). Some of these systems are installed at NPN sites. ETL and FSL will continue investigating the use of GPS receivers (surface and space-based) to achieve real-time, continuous observations of atmospheric water vapor for weather forecasting, climate monitoring, and satellite data calibration and validation. NRT GPS-IPG data with approximately 30-minute latency is now being provided for testing and evaluation.

FSL is investigating the use of superpressure balloons in the stratosphere as a platform for monitoring and observing the environment. Among the balloons' capabilities would be atmospheric soundings. The trajectory of the balloons could be controlled to some extent by adjusting their altitude so as to take advantage of the vertical shear. The balloons would carry compact, light-weight sondes whose locations could be tracked as they fell toward the surface. The balloons would comprise a moderately priced global system.

A number of engineering tests have already been performed at altitude by piggybacking on a zero-pressure balloon launched by the Physical Science Laboratory at New Mexico State University. Telemetry was received line-of-sight from a distance of over 200 miles, the storage batteries were charged by solar panels, the proper thermal environment was maintained during the daytime heating cycle, and the instrument package was successfully recovered after descent by parachute. In FY 2001, a 60-foot diameter superpressure balloon will be tested with an instrument payload.

During FY 2001, ETL and FSL will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. One effort involves the extension of wind profiler (RASS) and other data sources to develop humidity profiles through the planetary boundary layer. Other efforts include developing tools and techniques to integrate the data from surface-based and satellite-borne profiling systems for more effective use of these data in forecasts. In support of this effort, ETL has recently added a satellite remote sensing group that uses data from various environmental satellites to study air-sea interaction processes, the global hydrological cycle including water vapor and precipitation, and the Earth's radiation budget.

In a new development, ETL has demonstrated that tornadoes can be detected well before touch down by listening for their unique infrasonic signatures. Infrasonic antennas located in the central United States have been used to detect and locate numerous tornadoes. Verification has been provided by Doppler radar and visual sightings. This research effort is continuing and it is proposed that a network of these inexpensive infrasonic systems be deployed at WSR-88D sites to enhance early detection capability.

ETL will also continue development of Lidars and infrared Doppler multi-frequency radars as research tools to improve our knowledge of atmospheric winds, turbulence, and moisture processes. Development of dual-polarization Doppler and multi-frequency radars and passive radiometers will also be undertaken to study convective storms and their precursors, including in-cloud and entrainment processes. ETL will also continue research in the area of ocean remote sensing, including theoretical and experimental studies of rough surface scattering processes. In particular, ETL has demonstrated the potential application of Cold War-era over-the-horizon (OTH) surveillance radars for the large-scale mapping of ocean surface currents and winds. ETL is also developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities, including surface winds.

The discussion of observing technologies would be incomplete without mention of the North American Atmospheric Observing System (NAOS) Program. The overriding purpose of NAOS is to make recommendations on the configuration of the upper air observing system over North America and adjacent water areas. Government organizations and universities in Canada, Mexico, and the United States support NAOS. About 15 agencies from these countries have representatives on the NAOS Council, which identifies issues, sets priorities, coordinates the work of the program, and seeks financial support. Eventually, the council will advise governments on how to: (1) improve the utility of existing observing systems and reduce costs, (2) design a cost-effective observing system for the 21st Century, and (3) evolve toward that system from the present one. OAR representatives serve on the NAOS council and its two principal working groups.

The NSSL, known for its role in the development of the WSR-88D NEXRAD radar, continues to improve the software algorithms used by the NWS forecasters. NSSL is also exploring ways to enhance the WSR-88D hardware using dual polarization techniques. The first step in this process is to prototype a new Radar Data Acquisition (RDA) for the WSR-88D capable of processing the additional information to produce the dual-polarization information. The next step will be to implement dual-polarization on the NSSL's WSR-88D research radar.

Tropical Atmospheric Research

The Tropical Dynamics and Climate Program of the Aeronomy Laboratory (AL) is using a network of remote-sensing wind profilers in a long-term study of tropical circulation and its impact on global climate. The Trans-Pacific Profiler Network consists of an array of wind profilers that make continuous measurements of atmospheric winds and other parameters in the tropical Pacific. In addition to 50-MHz wind profilers, the network is incorporating 915-MHz lower tropospheric wind profilers developed at AL. The observations, which extend from the boundary layer to the lower stratosphere, reveal the relationship between atmospheric vertical motions and convective systems in the tropics. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. The network will: (1) provide valuable improvements to the boundary layer and convective parameterization schemes used in general circulation models and (2) contribute to climate forecasting by furthering the understanding of the coupled ocean-atmosphere dynamics that governs the El Niño-Southern Oscillation (ENSO) phenomenon, the dominant component of interannual climate change. A description of the TPPN and access to the data can be found on the AL web page *www.al.noaa.gov/WWWHD/pubdocs/ElNino.html*.

Routine wind observations are made at Christmas Island using 50-MHz and 915-MHz profilers. Lower tropospheric wind measurements using 915-MHz profilers are made at San Cristobal, Ecuador; and Tarawa, Kiribati. In addition, surface and upper air measurements are being made at Nauru and Manus Island, Papua, New Guinea at sites collocated with the Atmospheric Radiation CART Sites (ARCS) maintained by the

Department of Energy (DOE), Atmospheric Radiation Measurement (ARM) program. The wind data are assimilated into the analyses and forecast models of the European Centre for Medium-Range Weather Forecasting (ECMWF), NCEP, and other meteorological centers. The data are also used by climate researchers to support investigations of the variability of tropical circulation systems.

A recent focus of research with profilers has been to support Ground Validation Field Campaigns for the NASA Tropical Rainfall Measuring Mission (TRMM). Profilers were operated in a vertical-only mode to observe the vertical structure and temporal evolution of precipitating cloud systems in the Texas Florida Underflights campaigns (TEFLUN) in April-May 1998 and August-September 1998, the TRMM LBA campaign in Brazil in January-February 1999, and in KWAJEX campaign in August-September 1999. In addition, a profiler was operated on the *R/V Ronald H. Brown* (Figure 3-DOC-8) during Nauru99 and KWAJEX to observe the vertical structure of precipitating cloud systems. The profiler observations are being made available to the TRMM Science Team. They will be the subject of collaborative research with other TRMM researchers in the coming years with an emphasis on the use of profilers to calibrate scanning radars used for TRMM ground validation research and the use of profilers to retrieve drop-size distributions and related precipitation parameters of interest to the TRMM Science Team.

Severe Weather Analysis and Forecasting Research

The NSSL in Norman, Oklahoma, focuses on research to understand and forecast severe weather systems and their associated hazards, such as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. In addition, work includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, including research and development, for the WSR-88D program. In FY 2001, NSSL will continue to develop techniques in cooperation with the NWS to forecast and warn of weather hazards

Figure 3-DOC-8. NOAA Research Vessel Ron Brown.

to aviation and the general public. Work with the resultant data from the 1994-1995 VORTEX experiment and subsequent experiments like MEaPRS is continuing to provide new understanding of severe thunderstorms and the tornadoes that they spawn, to improve ways to model and predict these storms, and to provide new generation algorithms for severe storm detection. Immediate technology transfer will be effected by close association with the WFOs, such as those in Norman and Tulsa, Oklahoma; Phoenix and Yuma, Arizona; Melbourne, Florida; Pittsburgh, Pennsylvania; St. Louis, Missouri; Missoula, Montana; Reno and Las Vegas, Nevada; Jackson, Mississippi; Atlanta, Georgia; Fort Worth, Texas; Denver, Colorado; and Salt Lake City, Utah.

In addition, NSSL is continuing to work closely with the NWS WSR-88D Operational Support Facility to re-host the Radar Product Generator, the Radar Data Acquisition system, and also the Principle User Position to an open system platform. The re-hosting will continue for the next several years and will result in improved capabilities for the WSR-88D. The new system will ease the incorporation of new applications, speed technology transfer, allow for incorporation of new hardware technology, and increase the portability of the software.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. FSL develops and evaluates state-of-art workstations for forecast office environments. Specifically, FSL has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. By maintaining state-of-the-art capability for use in research and development of operational techniques, it continues to provide a mechanism to evaluate weather service requirements for AWIPS.

FSL will continue efforts toward effective assimilation of diverse observational data into numerical prediction models. Data from the Aeronautical Radio Incorporated (ARINC) Aircraft Communications, Addressing, and Reporting System (ACARS), WSR-88D Doppler radars, the NOAA Profiler Network, and weather satellites, especially GOES, are frequent and provide unprecedented resolution, either in the vertical or the horizontal, or both. These data are being more

fully exploited in the Local Analysis and Prediction System which provides highly detailed analyses and forecasts over areas hundreds of kilometers on a side, and the Mesoscale Analysis and Prediction System, the basis for operational and frequent short-term forecasts for the lower 48 states. The system has been incorporated into the AWIPS system and is being used by a number of other agencies, not only for various regions of the United States, but for a number of regions throughout the world.

OAR will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and NSSL is participating directly in training programs, such as the COMET in Boulder, Colorado, and the WSR-88D Operational Support Facility in Norman, Oklahoma.

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ETL and NSSL, the NWS Seattle WFO, NCAR, and the University of Washington. Support for the program is also being provided by the Office of Naval Research. This research improves understanding of the effects of prominent terrain on West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds, precipitation, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in FY 1994 and 1996, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of strong fronts and, in one case, an intense, landfalling low. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. Follow-up field programs in FY 2001 and FY 2002 will focus on cloud and precipitation processes using special observations from research aircraft and land-based radars. The results are providing information on how to improve forecasts of Northwest weather.

Taking advantage of the 1997-98 El Niño event, ETL led the California Land-Falling Jets Experiment (CALJET) with participation by PMEL (OMIC), FSL, the Naval Research Laboratory (NRL), and the Naval Post Graduate School. CALJET took place between December 1997 and February 1998 and was designed to study the development of the pre-frontal low-level jet along the coast of California. This moist jet can cause severe, flooding rains along and near the coast as it impinges on the coastal mountains. The large volume of data gathered during this experiment, including those data from the NOAA WP-3 and from an array of radar wind profilers along the coast, was analyzed throughout FY 1998-99 to determine the mechanisms of jet development. This knowledge was incorporated into numerical models to improve the accuracy and lead time of forecasts of heavy, flooding coastal rains in California. This study is occurring with close cooperation between the scientists and the NWS forecasters in California (Figure 3-DOC-9).

Figure 3-DOC-9. CALJET sensor package

Mesometeorology and Precipitation Forecasting and Warning Research

NSSL develops techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Studies underway include the precipitation structure of mesoscale convective systems, the interactions between mesoconvective systems and the larger environment, the use of satellites to infer storm development and rainfall, short-range ensemble forecasting techniques, and winter storm forecasting procedures. In FY 2001, NSSL will continue to use polarization information to improve radar estimates of rainfall that will be the key to improving short-term flash flood forecasts. NSSL also continues to investigate various model convective parameterization schemes, along with our continued effort to improve model initialization through four-dimensional data assimilation.

In addition, NSSL is working with the NWS Storm Prediction Center (SPC) to improve their ability to forecast severe weather including winter weather events. Several new severe

storm and tornado climatologies have been completed. New experimental forecasts are now being produced by the SPC that include the probabilities of occurrence of severe weather. NSSL and SPC continue to improve the capability to forecast winter weather events and refine their ability to provide severe winter weather guidance products. In FY 2001, NSSL will continue to support the SPC by providing improved methods for severe weather forecasts including winter weather and flash floods.

Hurricane Analysis and Prediction Research

The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory (AOML) explores hurricanes in dedicated research flights aboard the WP-3D aircraft operated by NOAA's Aircraft Operations Center (AOC). The P-3s carry a suite of instruments to measure a wide range of meteorological quantities, including standard flight-level data, precipitation characteristics, remotely-sensed surface winds, vertical soundings, ocean thermal structure, radar reflectivity, and Doppler radar winds. In addition to the airborne observations, HRD develops techniques for real-time analysis and display of hurricane data, especially of surface winds. It also carries out modeling and theoretical studies closely tied to the observational program and studies interannual and inter-decadal changes in hurricane activity.

The 1995-1999 hurricane seasons were the five most active consecutive ones in the >100-year quantitative climatology. There is a growing body of evidence indicating that the relatively low level of hurricane activity experienced in the 1970s and the 1980s is over and that the first decade or two of the 21st Century will see a return to the more active conditions that characterized the 1940-1960s. If this hypothesis proves true, land-use and development decisions made over the last two decades may be inappropriate to the present hurricane climatology and the need for more accurate forecasts and better informed policy guidance will become pressing.

An exciting new tool for this effort is AOC's newly commissioned Gulfstream IV (G-IV) jet which has operated successfully in the hurricane environment since 1997. The G-IV extends the envelope of observations throughout the depth of the troposphere. Use of these aircraft presents an unprecedented opportunity for better understanding and forecasting of hurricanes through detailed observations. Of special interest are the hurricanes' inner core, the oceanographic and upper tropospheric synoptic-scale forcings that control intensity and motion, and the kinematics and thermodynamics of the near-surface boundary layer. The GPS-based dropsondes procured as the G-IV's main scientific payload have a vital role in these investigations because of their high vertical resolution and superior thermodynamic and wind sensing capability. The 1998 season constituted the first major field program for HaL carried out in collaboration with NASA's Third Convection and Moisture Experiment (CAMEX-3). The success of this campaign combined with follow-on missions in 1999 was unprecedented. NOAA and NASA aircraft flew a combined total of more than 100 scientific sorties in 1998 and 1999. Participation by the G-IV and NASA's DC-8 and ER-2 provided extensive *in situ* observations above the middle troposphere for the first time since the 1960s. In addition to airborne measurements, university teams with instrumented towers, mobile Doppler radars, and portable profilers coordinated with HRD to obtain detailed measurements of near-surface conditions in most hurricanes that passed onshore during these seasons. Current plans are to repeat the 1998 campaign in conjunction with CAMEX-4 in 2001.

The motivation for acquisition of the G-IV was a statistically rigorous demonstration, based upon more than a decade of experiments with the P-3s, that intensive observations of the flows surrounding hurricanes can produce substantial (16-30 percent) reductions in track forecast errors. Data from multiple-aircraft experiments involving the G-IV and both WP-3Ds should confirm the GI-V's ability to improve forecasts. Adaptive targeting of aircraft observations to regions where they will do the most good is a strategy to realize even further improvement.

The forecast system currently has limited skill in prediction of intensity. Though continuing research with the expanded aircraft fleet, the Nation can realize large (billions of dollars per year) economic benefits through more accurate routine operational track forecasts. A second, equally significant, outcome is the promise of dynamically-based, skillful intensity forecasts. Because hurricanes inflict huge costs on the United States economy, even incremental improvements in forecasts have large benefit to expenditure ratios. The report on HaL by the USWRP Prospectus Development Team 5 (PDT5) contains a comprehensive, focused scientific strategy to realize these benefits (BAMS, 79, 305-323).

In addition to HRD research activities, the OAR scientists carry out hurricane research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. GFDL's Hurricane Dynamics group performs hurricane modeling research to study the genesis, development, and decay of tropical storms using multi-nested three-dimensional computer models of the hurricane system and its surrounding environment.

In the early 1990's, this research model proved so successful for simulation of observed storm behavior that the NWS adopted a version of it for

use in operational forecasting. From the 1995 through the 1999 hurricane seasons, the GFDL Hurricane Prediction System provided the most accurate hurricane-track forecast guidance available and contributed substantially to the dramatic error reductions in official forecasts that have occurred since its introduction.

Numerical Analysis and Prediction Modeling

As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved NWP models. Three groups at GFDL are engaged in weather research activities: Experimental Prediction, Mesoscale Dynamics, and Hurricane Dynamics (described above).

Experimental Prediction at GFDL develops and improves numerical models of the atmosphere-ocean-land system in order to produce useful weather forecasts with lead-times ranging from weeks to seasons and beyond. The group is pursuing several avenues of research to achieve such improvements. First, GFDL scientists are investigating methods of stochastic dynamic prediction in order to extract as much forecast information as possible from numerical prediction models, given imperfectly observed initial conditions. In addition, laboratory scientists are developing methods for the assimilation of ocean observations into prediction models in order to improve the forecast of the atmosphere and the ocean.

Mesoscale Dynamics at GFDL develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies.

The FSL implemented a Rapid Update Cycle (RUC) at NCEP in 1994. The RUC gave a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in February 1998. This new version operates at 40-km horizontal resolution with 40 vertical levels and provides updates every hour, thus, incorporating information from virtually all high frequency data sources: hourly wind profiles, WSR-88D (Doppler radar) velocity azimuth displays, ACARS reports (up to 65,000 per day), cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites, and surface observations.

The new RUC also includes explicit forecasts of cloud droplets, ice crystals, raindrops, snowflakes, and graupel (snow pellets). This improves forecasts of precipitation type. The RUC exploits a new, multi-level soil and vegetation model to improve forecasts at and near the earth's surface. With the arrival of a larger computer at NCEP, the way is open for expanding the geographical domain of the RUC and moving toward finer resolution of the computational grid (20-km). The 20-km version of the RUC is expected to become operational in FY 2001. The new version will also incorporate a three dimensional variational (3DVAR) analysis that will replace the optimum interpolation method used earlier.

Along with NCAR, NCEP, and a few universities, FSL is collaborating on the development of a new mesoscale model, the Weather Research and Forecast (WRF) model. The goal of this development, from the beginning, is that the WRF model should become a community model and a tool both for experimental and operational prediction, thus paving the way for quick realization of research advances in forecast dissemination to the public and industry. A management plan has been published, and working groups are organized to pursue various aspects of development.

The Air Resources Laboratory is also involved in the development of new models for operational use by NCEP. The main focus is on mesoscale models and in the development of new capabilities for data assimilation. In particular, the new generation of mesoscale models (such as the WRF model referred to above) will require advanced descriptions of the coupling between the air and the surface, a matter that is being studied intensively in ARL programs involving closely interacting measurement and modeling activities. ARL conducts research on the surface energy balance and on the spatial variability of surface fluxes using aircraft. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as of emissions from sources like volcanos and industrial enterprises. In recent work, ARL is developing a new system for forecasting the dispersion of smoke from forest fires, in collaboration with the Association of South East Asian Nations and their Regional Haze Action Plan.

Air Quality Research

The principal mission of the Air Resources Laboratory (ARL) is to improve the capability to forecast changes in air quality and atmospheric deposition. Deposition is the factor that links the pollutant characteristics of the air with the terrestrial and aquatic environments. ARL's research focuses on the lower atmosphere, where the atmosphere is in direct contact with other media--aquatic, terres-

trial, and biospheric. The core of ARL research relates to studies of the atmosphere as a component of the total environment. Much of this work is in collaboration with other parts of NOAA (principally NCEP) and with other agencies, such as EPA, DOE, and DOD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs, and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards. The Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models. The Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales, and specializes in the development of high-technology airborne instrumentation (for both aircraft and balloons). The Special Operations and Research Division, in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. SORD also serves as the main NOAA facility working with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA) of the University of Nevada system.

ARL operates two national networks that focus research on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-run Integrated Surface Irradiance Study (ISIS) serves as the national array of monitoring stations for solar radiation (and ultraviolet-B) with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. Many of the SURFRAD stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. Thus, the SURFRAD program is evolving into one of complete energy balance with supporting data on carbon dioxide exchange. This work forms an intersection with the new flux measurement networks in the United States and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing areal air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. To test the aerial integration capabilities, ARL has instrumented an aircraft of the NOAA fleet (a DeHavilland Twin Otter) to measure all of the eddy fluxes as well as a number of trace gas exchange rates. This instrumented aircraft has been used in several field experiments and has already demonstrated that considerable error can result when local values are inappropriately taken to represent larger areas.

ARL also provides forecast support to NOAA's emergency response systems with emphasis on nuclear and volcanic events. For this application, ARL develops and couples advanced mesoscale models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. Users also may access these products through the Internet.

The Aeronomy Laboratory (AL) coordinates a NOAA/OAR air quality research effort, the Health of the Atmosphere research. NOAA's Health of the Atmosphere research is focused on the atmospheric science that underlies regional and continental air quality, with the goal of improving our ability to predict and monitor future changes, leading to improved scientific input to decision-making. NOAA/OAR's Aeronomy Laboratory, Air Resources Laboratory, Climate Monitoring and Diagnostics Laboratory, Forecast Systems Laboratory, and Environmental Technology Laboratory participate in the research. The Health of the Atmosphere research goals are:

- Characterize regional ozone episodes: Characterize the origin of ozone in rural areas, where crop and forest damage are of increasing concern. In 1999, a comprehensive air quality field experiment took place in the region around Nashville, Tennessee. In the summer of 2000, Houston will be the site of an experiment to investigate the complex chemical and meteorological factors that influence the air quality of that coastal region. The regional chemistry is of special interest because of the presence of large natural as well as anthro-

pogenic sources of hydrocarbons (including the petrochemical industry) and because of the unique influence of coastal meteorology on air quality of the region.

- Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the Atmospheric Integrated Research Monitoring Network (AIRMoN) and the ozone profiling network).
- Develop a better understanding of the fundamental science underlying the processes responsible for the formation and distribution of fine particles in the atmosphere: Improve the atmospheric predictive capability that links sources of fine particles and their precursors to human exposure and visibility impairment. In 1999, an experiment was conducted in Atlanta to compare research capabilities related to the measurement of fine particles in the lower atmosphere.

In future Health of the Atmosphere research, the OAR Laboratories will integrate their meteorological, chemical, and forecasting expertise to build an assessment and prediction capability for regional air quality that incorporates the influence of multiple-time-scale meteorology/climatology. While the ambient levels of pollutants like ozone and fine particles are clearly dependent on pollutant emissions, a large fraction of the variation in those levels is driven by meteorology, both in the short term and longer term. Therefore, the key to assessing both the intended long-term improvements in air quality and the more-episodic variations lies in understanding not only the atmospheric linkages between emissions and concentrations, but also in understanding the coupled chemical and meteorological processes. This "chemical meteorology" research will extend the current program focus on emissions/concentration linkages to include a predictive understanding of the role of synoptic, seasonal/interannual, and longer-term meteorological/climatological changes on the chemistry of the lower atmosphere. The Air Quality Research Subcommittee of the Committee on Environment and Natural Resources (CENR) will provide the interagency collaboration at the United States Federal level. On the broader international arena, the coordinating body is the North American Research Strategy for Tropospheric Ozone (NARSTO), a tri-lateral public/private partnership focused on ozone and particulate matter research in the United States, Canada, and Mexico. NOAA is the public-sector co-chair of NARSTO.

ETL uses its suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone Lidars, Doppler Lidar, and supporting turbulence instrumentation to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments as well as in complex orography.

Space Environment Services

NOAA and the Air Force jointly operate the National Space Weather Operations group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. In FY 2001, SEC will stress six strategic elements that include:

- Improvement of space weather products.
- Obtaining critical new space environment observations.
- Transitioning space weather analysis techniques and models into operations.
- Continued implementation of a modern computer architecture.
- Development of new web pages for providing space weather products.
- Fostering of a commercial vendor community for space weather services.

The improvement of services is built around the theme of making space weather information human friendly. Toward the same objective, a new NOAA Space Weather Scale has been designed and announced to the community. Space Weather products have been reorganized to include advisories in plain English and then replacement of little known vocabulary with descriptors that are understandable beyond the immediate field of space weather. The work toward new observations includes:

- Final planning for ingesting observations from the Solar X-ray Imager telescope to be flown on GOES M and following GOES spacecraft.
- Real time images of global aurora from the IMAGE satellite (Figure 3-DOC-10).
- A prototype test flight of a Hard X-Ray Spectrometer Telescope designed to detect precursors of solar radiation storms. The flight is being flown as part of the Defense Satellite Program.

The new NOAA Weather Scale identifies three types of space weather disturbances and describes five levels of

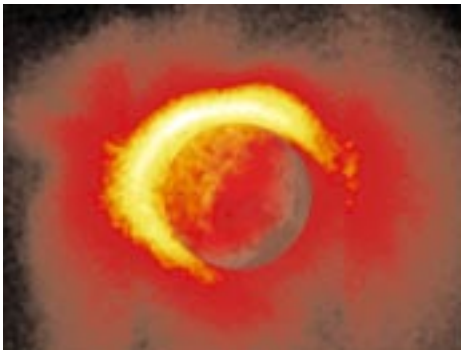


Figure 3-DOC-10. Ultraviolet image of sunlight scattered from the Earth's extended atmosphere of helium using the Extreme Ultraviolet Imager instrument. This image shows that the ionized helium atmosphere extends to about 2 - 3 times the size of the Earth. Irregularities at the fringe of the image, such as the upper left, indicate magnetic storm activity.

disturbance ranging from a Level 1--very mild to Level 5--extremely severe. The new web page design updates the SEC web page, an early leader in using the web to disseminate space weather alerts, warnings, and forecasts. With web page accesses exceeding one million per week and the increasing number of products and data, the old design had become unwieldy. The new pages will facilitate both experienced users and searchers new to the field of space weather.

The SEC, working closely with the Air Force's 55th Space Weather Squadron (55 SWXS), provides forecasts, alerts, indices, and summaries of disturbances occurring on the Sun, in space, in the geomagnetic environment, and in the upper atmosphere. The services are used by DOD, DOT, DOC, DOI, DOE, NASA, NSF, commercial users, and the research community:

- To optimize the operation of technical systems that are adversely affected by disturbances in the space environment.
- To carry out research in the solar-terrestrial environment.

Examples of the adverse effects include loss or reduced efficiency of communication systems, radiation hazards to personnel and systems in high altitude aircraft and in space, degradation of surveillance and monitoring systems for defense, errors in navigation systems, perturbations of satellite orbits, and disruptions in power distribution networks.

SEC serves as the international World Warning Agency for the solar-terrestrial environment. It collects international data--solar-wind, X-ray, sunspot, corona, magnetic, etc.--in real-time and, from these data, provides International URSIgram and World Days Service and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use. There is also a substantial and rapidly growing customer base in the private sector. SEC operates with observations received from agencies that contribute their data and, in return, receive the synthesized and integrated services to meet their needs. Agencies making major contributions of data include: DOD, NASA, DOC, NSF, DOE, and DOI. SEC cooperates directly with NESDIS to receive solar X-ray, particle, *in situ* magnetic field, and plasma data from the SEM on GOES and the polar-orbiting NOAA satellites. Data are collected, stored, and displayed for analysis and products and distributed to outside customers primarily via the Internet (*www.sec.noaa.gov*), by NOAA Weather Wire, and digital data links (primarily operated by other agencies). Radio broadcast, mail, and recorded telephone messages are available to users as well.

Over the past year, SEC has instituted a large number of new capabilities and products which represent a major leap forward in space weather services. New, real-time solar-wind data are allowing SEC to extend the warning time for several geomagnetic storms from 0 minutes (Nowcast) to up to 1 hour in advance. SEC's Rapid Prototyping Center (RPC) has flourished under a Cooperative Research and Development Agreement (CRADA) partnership. In March, 1998, SEC also initiated test products from the Magnetospheric Specification Model (MSM)--the first numerical model being transitioned into operations through the developing RPC mechanism. With its initial infrastructure and concept of operations developed through a CRADA partnership, the RPC is planned to grow into the primary mechanism for transitioning National Space Weather Program sponsored models into operations. In addition to these technical advancements, users will also benefit from 24 hour a day forecaster staffing implemented in October 1998.

Military

The United States Air Force operates the 55 SWXS in Colorado Springs, Colorado, to provide space weather support to DOD assets. The 55 SWXS operates and maintains the solar observing network with sites at Palehua, Hawaii; Learmouth, Australia; San Vito, Italy; Ramey, Puerto Rico; Sagamore Hill, Massachusetts; and Holloman AFB, New Mexico. The 55 SWXS shares space weather support responsibilities with its civilian counterpart the SEC.

Voluntary Observing Ship (VOS) Program

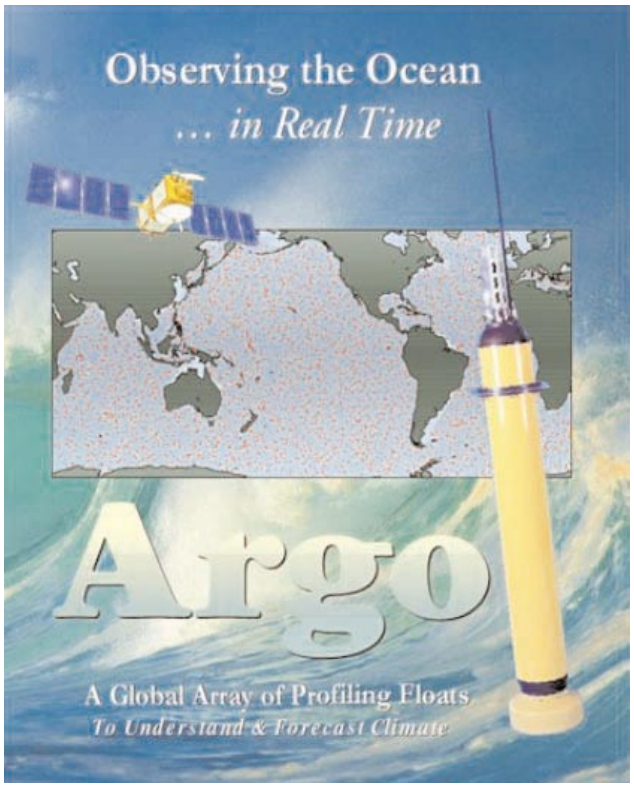
OAR operates a global VOS program that provides real-time meteorological and oceanographic data from selected vessels. Data are collected with the Shipboard Environmental Data Acquisition System, which transmits the information to NOAA via the GOES system. The information is then disseminated nationally and internationally using existing data networks. Presently, there are over 120 vessels in the program which record and transmit surface meteorological information four times per day at synoptic hours. Of these vessels, about 60 vessels are also equipped to collect expendable bathythermograph data.

Southern Hemisphere Drifting Buoy Program

In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, OGP, AOML, and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere. The buoys measure sea-level atmospheric pressure, air temperature, and sea water temperature. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites.

The TAO/TRITON array consists of approximately 70 ATLAS and TRITON moorings in the Tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the Argos satellite system. Designed to improve detection, understanding, and prediction of El Niño, TAO/TRITON is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS). The array is supported primarily by the United States (NOAA) and Japan (JAMSTEC) with contributions from France (IRD) and Taiwan (NTU). The mooring array is operated and maintained by the TAO Project Office located at PMEL in Seattle, Washington, which has responsibility for project management, operations and logistics. These buoys provide climate researchers, weather prediction centers, and scientists around the world with real-time data from the tropical Pacific. El Niño (the warm phase of the ENSO cycle) is associated with a disruption of the ocean-atmosphere system in the tropical Pacific and has important consequences for weather around the globe. A description and overview of the TAO/TRITON Array is available at *www.pmel.noaa.gov/toga-tao/overview1.html.*

PIRATA (Pilot Research Moored Array in the Tropical Atlantic) is a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, interannual and longer time scales. It consists of an array of 12 ATLAS moorings similar to those deployed in the Pacific.



Global Drifter Program

The Atlantic Oceanographic and Meteorological Laboratory, in Miami, Florida, manages the deployment of drifting buoys around the world, deploying some 300 new drifters annually and tracking nearly 700. Using research ships, Volunteer Observation Ships (VOS), and United States Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified operational, they are reported to AOML's Data Assembly Center (DAC). Incoming data from the drifter are then placed on the Global Telecommunications System (GTS) for distribution to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

ARGO--Global Array of Profiling Floats--will deploy a global array of 3,000 profiling floats to better understand and forecast climate. ARGO floats will be parked at 1,000m and will profile the water column from the surface to 2,000m. Observations will be made in real-time. Along with satellites, ARGO will initiate the oceanic equivalent of today's operational observing system for the global atmosphere.

NOAA Ship *RONALD H. BROWN*. NOAA recently installed and deployed a 5-cm Doppler precipitation radar to conduct studies of atmospheric processes over the ocean. The system has been shown to not only be effective for studying convective processes but also processes associated with marine stratus clouds. In late 1999, NOAA will install a next-generation shipboard wind profiler on the *RONALD H. BROWN* that is presently in development at the ETL. This profiler will be electronically stabilized (as opposed to the mechanically stabilized systems used on board ships to date) and will employ some new clutter-screen techniques to reduce interferences and obtain profiles much closer to the surface than have been possible to date.

The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to maintain a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the Federal Government responsible for the health and safety of our Nation's coastal and oceanic environment. NOS acquires water levels, currents, winds, and other physical oceanographic and meteorological data, and distributes these data and circulation predictions as elements of an integrated NOS program (Figure 3-DOC-11). This integrated program provides a comprehensive science-based suite of information products required by the marine transportation community to ensure safe and efficient marine transportation, including the transport of oil and other hazardous materials. Also, NOS provides coastal oceanographic and meteorological products required by the National Weather Service (NWS) to meet its short-term weather and forecasting responsibilities, including tsunami and storm surge warnings/forecasts.

National Water Level Observation Network (NWLON). NOS manages the NWLON, stations located along the coasts of the United States and the Great Lakes, from which water level data, as well as other oceanographic and meteorological data, are collected and disseminated. NWLON provides a number of NOAA and other Federal programs with data and supporting information, such as the NOAA Tide and Tidal Current Prediction program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate and Global Change Program.

An event triggered NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS when the water level exceeds a specified high/low limit or when the rate of change between the standard 6-minute water level values exceeds a specified value.

The NOS Continuous Real-Time Monitoring System (CORMS), now operational, was designed to operate on a 24 hour/7 days a week basis to ensure the accuracy of tide and current observations acquired via the National Water Level and Physical Oceanographic Real-Time System (PORTS™) Programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability from disseminating inadequate data, and makes the observations more useful for all applications. CORMS ingests real-time data from all field sensors, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data.

Physical Oceanographic Real-Time System (PORTS™). PORTS™ is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS™ measures and disseminates observations and predictions of water levels, currents, salinity, and many meteorological parameters, e.g winds and visibility, needed by the mariner to navigate safely.

PORTS systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. The largest of NOS' existing PORTS™ installations is comprised of over 26 separate instruments. The smallest consists of a single water level gauge and associated meteorological instruments, i.e. winds, barometric pressure, etc.

Regardless of its size, each PORTS™ installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting United States ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of dollars and destroy sensitive marine habitats critical to supporting

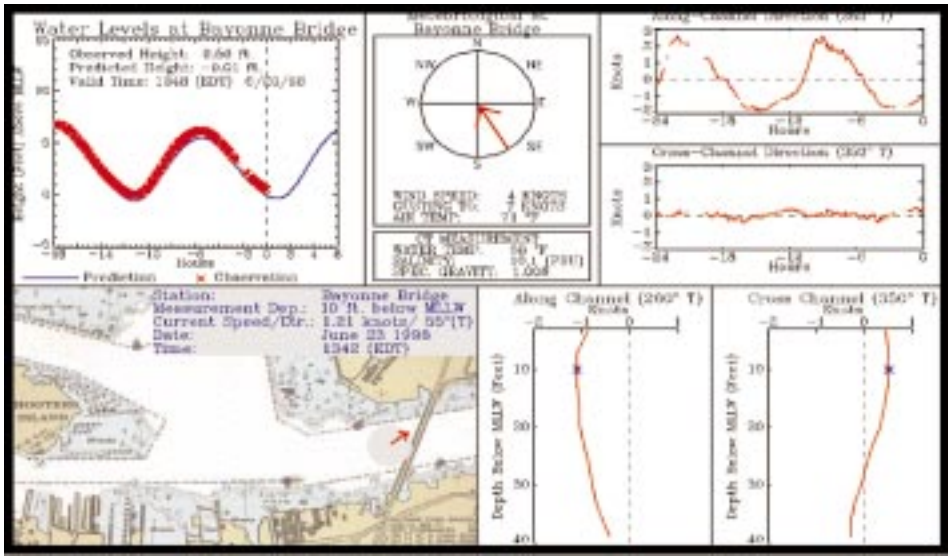


Figure 3-DOC-11. NOS web information of current, water level, and meteorological data for New York/New Jersey Harbor area shipping.

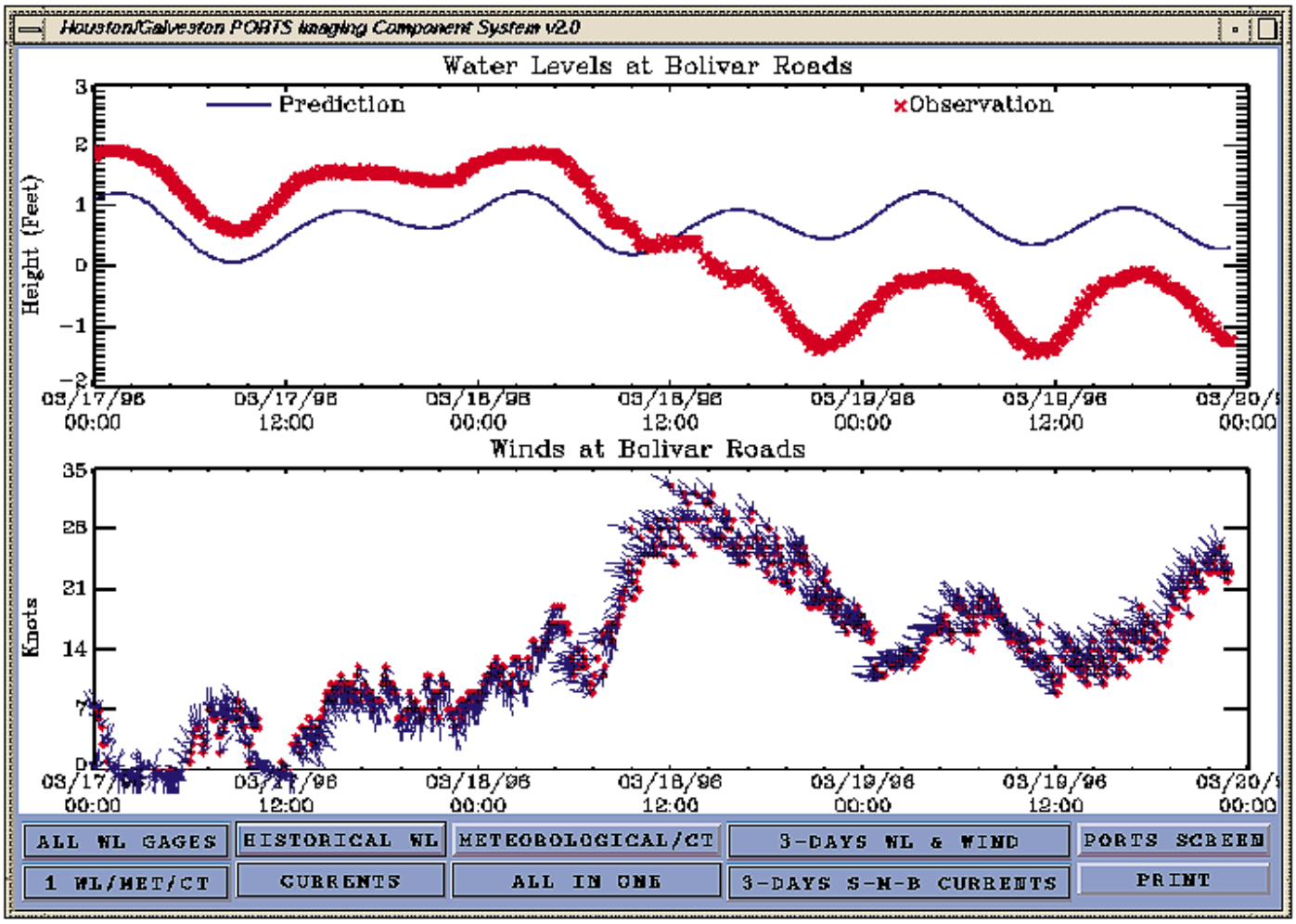


Figure 3-DOC-12. Meteorological influences on coastal water levels. NOS provides information that warns of abnormal conditions, i.e., water levels lowered by the wind.

coastal marine ecosystems. PORTS™ provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur.

An extensible PORTS™ can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS). Also, new developments will enable PORTS™ to incorporate biological and chemical sensor systems and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management.

The integration of PORTS™ technology and numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even at locations where physical measurements are not available (Figure 3-DOC-12). The Chesapeake Bay Oceanographic Forecasting System (CBOFS) is an NOS project that provides forecasts of total water level within the Bay in addition to the astronomical tidal prediction. Using wind observations from multiple locations to help force the model, the 1-year root mean square difference between the modeled and observed water level at Baltimore is 9.4 cm.

OFFICE OF NOAA CORPS OPERATIONS
AIRCRAFT OPERATIONS CENTER

The Aircraft Operations Center (AOC) provides aircraft support to many NOAA missions, several of them associated with the Natural Disaster Response Initiative (NDRI). In particular, AOC operates a fleet of aircraft to support NOAA's research and development programs to improve weather, marine, and climate services. It provides hurricane reconnaissance and surveillance support to NOAA's National Hurricane/Tropical Prediction Center with its Lockheed WP-3D and Gulfstream IV (G-IV) aircraft as well as flight services to other federal agencies and international programs approved by NOAA's Aircraft Allocation Council. AOC's light aircraft provide aerial photography for nautical and aeronautical charting and living marine resources surveys.

AOC was established in October 1983 through a consolidation of all existing NOAA organizations and elements operating NOAA aircraft. This consolidation was accomplished to achieve a more efficient, more economical and safer operation of NOAA aircraft. Fourteen aircraft, located throughout the United States, are managed by AOC from its home base at MacDill AFB in Tampa, Florida.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, are supported by two WP-3D Lockheed Orion aircraft which carry a full array of state-of-the-art environmental research instrumentation. The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. AOC develops and calibrates specialized instruments, integrates user-supplied instrumentation into its automated dated recording systems, and processes and analyzes data sets collected during various field programs.

AOC recently integrated into its operation a new, high-altitude jet, the G-IV, which is used for hurricane surveillance. This aircraft flies in the environment surrounding hurricanes at altitudes up to 45,000 feet. The G-IV dispenses the new GPS dropwindsonde and transmits the resulting profiles of thermodynamic and wind information to the NCEP and the NHC for inclusion in their computer prediction models. Initial estimates of the improvement in hurricane track predictions is between 20 and 30 percent, and these improvements are expected to result in future savings of $10 million or more per hurricane in warning and preparedness costs. With its high-altitude capability, the G-IV is the central focus for additional research leading to improvements in hurricane intensity forecasts. The aircraft will also be used for air chemistry studies and other research in the upper troposphere.

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also provide storm data to the NHC in near real time, transmitting flight level data, dropwindsonde messages, and radar images via its aircraft-satellite data link. The AOC aircraft have primary reconnaissance responsibility for tropical storms and hurricanes in foreign airspace and also augment Air Force Reserve aircraft reconnaissance during particularly active storm periods when tasking requirements exceed available resources.

Land-falling hurricanes, a major subject of the USWRP and NDRI, receive particular attention from AOC aircraft. During the 1998 hurricane season, the G-IV and the WP-3D aircraft flew a combined total of over 400 surveillance, reconnaissance, and research hours on Atlantic storms that made or nearly made landfall in the continental United States. Joining with the AFRES and NASA aircraft, the three NOAA planes participated in the first multi-agency hurricane research experiment since STORMFURY, a hurricane modification project that took place in the early to mid-70's. The Convection and Moisture Experiment III (CAMEX-3) experiment focused on the measurement of cloud moisture using a variety of space-borne and aircraft mounted remote sensors.